Railway Age

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DAILY EDITION

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Checking Up Committees

Do all of the committees of the Mechanical Division make good on their assignments? If not, are they taken to task or are they made to feel the displeasure of the organization? Of all the railroad technical associations the American Railway Engineering Association is probably most exacting in insisting upon a creditable performance by its committtees. When a committee report is being presented or discussed the entire committee sits behind a long table facing the audience. The chairman of the committee may present the report, or he may introduce it and call upon one or more of his associates or sub-chairmen to present or discuss those parts of it which they are particularly qualified to speak upon. The convention itself does not hesitate to express pleasure or displeasure if a committee makes a particularly good report, or if, on the other hand it falls short of what may reasonably be expected of it. In the latter event it is exceedingly embarrassing to the chairman and the members of the committee—so much so that they put forth special efforts to prevent becoming the objects of such censure. It is a question, however, whether the embarrassment is greater at the moment than during the succeeding days and months when the committee members are the targets of ridicule on the part of their friends in the association on their own and other roads. Is this not a good standard to set and ought not the Mechanical Division take steps to develop a similar spirit These comments, by the way, have no reference to this year's reports. The suggestions came to us quite some time ago and before the present reports were printed or available.

Secure Sufficient Data for Estimating an A. F. E.

It is the customary procedure for railroad companies to prepare machine tool budgets early each year. The number of machine tools that the railroad man can purchase out of any given appropriation depends largely on the accuracy with which such estimates are prepared. Every mechanical department officer concerned with the preparation of an A. F. E. is thoroughly impressed with the importance of making his estimate high enough. The result is that in the great majority of cases the estimates are made from 15 to 25 per cent too high. It is evident, therefore, that when these estimates are added to each other, the total number of machines represented is much less than would have been the case if the estimates had been more accurate. An instance of this is where a mechanical department expended only $120,000 out of a total appropriation of $150,000, thereby losing an opportunity to secure $30,000 worth of tools which the management was willing to purchase, but which were not purchased because of the extra amount added in estimating the A. F. E. It may be contended that the unexpended $30,000 would be available later on, as soon as the various accounts had been closed and the unexpended balance determined. This is possible, but it seldom occurs, because business conditions change. If the mechanical department should call attention to the fact that its estimates were in error to the extent of $30,000, it would not necessarily be allowed to make the additional expenditures to absorb this balance. In order to make a correct estimate for an A. F. E., the mechanical department should have detailed information on the cost of machinery and installations. A great deal of this information should be available from railroads which have made recent additions of new shop equipment. Accuracy in making the estimates can also be facilitated by keeping complete records of previous purchases and installations. However, both the railroads and the maufacturers can profit by a get-together policy of seeing that the mechanical officer has sufficient and correct data for making out his budget.

Lowering Shop Production Costs

Given reasonably good equipment and reasonably capable workmen, efficient shop production becomes largely dependent upon the smooth and even supply of materials or repair parts. In other words a maximum of efficient and economical production is not possible unless each shopman is permitted to work steadily and continuously at the particular class of work to which he has been assigned and for which he has been trained. This does not mean that a shop man may not be employed at various times on various classes of shop work, for flexibility of this nature is extremely necessary, particularly at smaller shops. It does mean, however, that no conditions should be tolerated that will keep him from producing a maximum output either with machine tools or in any other of the operations of the shop. This naturally brings up the question of the delivery of material and in itself should render wholly impracticable the frequently followed

practice of allowing mechanics or other employees of a like grade to call at storehouses and secure, or in some cases to arrange for the delivery of the material necessary for the further prosecution of their work. From the standpoint of the shopman, this practice is not objectionable for reasons entirely obvious. From the standpoint of the railroads, it is an expensive and wasteful proposition of which the loss in man-hours is only a small part, although it may and often does run into a large sum in the course of a year. The real loss lies in the decreased production and the consequent higher unit charges for repairs represented in bulk by interest charges on a heavy investment for buildings and facilities—stating it briefly, the overhead is needlessly increased. Thus, while appearing on the surface to be but a minor incident in the operation of a railroad shop or shops, the delivery of material forms an important factor which must have considerable study and attention if still lower production costs are to be secured.

Locomotive and Car Lighting

The report presented yesterday on the subject of locomotive and car lighting was very brief and the discussion appeared to be perfunctory. This should not, however, create in the minds of the listener the impression that the paper was unimportant or poorly handled. The subject is an important one and the report is the result of systematic work on the part of a large number of electrical men. The subject matter in the report was originally prepared by two committees of the Association of Railway Electric Engineers, one working on locomotive lighting and the other on car lighting. These reports were presented to that association and discussed by the members. The results on this work were then taken by the Committee on Locomotive and Car Lighting of the Mechanical Division, and boiled down into the concise and meaty report presented yesterday morning. It was accepted and submitted to letter ballot. This method results in the saving of much time on the convention floor for the Mechanical Division and provides a double check against errors in the report submitted for ballot.

Crane Facilities in Locomotive Shops

It is not unusual to find locomotive shops inadequately equipped with traveling cranes to handle locomotives and their auxiliary parts. As a result of this condition considerable time and money is lost by the workman waiting for a lift in order that he may proceed with his work. Antiquated shops usually are equipped with locomotive-handling cranes which do not have sufficient capacity to handle modern power with dispatch and a sufficient margin of safety. Considering that many locomotive repair shops are handling modern size power they should be equipped with traveling cranes of at least 200 tons capacity. To obtain the most economical results from the cranes, it should be determined how many pits one locomotive-handling crane should serve. A careful study should be made of the number and class of repairs handled in conjunction with the number of gangs of men employed to make these repairs so as to allot to each crane the correct number of erecting pits. The Committee on Design of Shops and Engine Terminals, developed the fact that the majority of the railroads favored from twenty to thirty pits as giving the most satisfactory results. Since it is not an economical operation to use locomotive-handling cranes for auxiliary parts in the erecting aisle, careful consideration should be given to the capacity and number of traveling cranes for this class of lifting. If suitable small capacity jib cranes are not available, considerable time and money is lost by workmen waiting for lifts to complete their work. In any repair shop that is inadequately supplied with jib or other auxiliary cranes, it will invariably be found that workmen are standing around idling away time until the service of a crane is available.

Proper Locomotive Lubrication

A lengthy discussion resulted during Wednesday's meeting on the relative merits of the hydrostatic and the force feed lubrication. It obviously favored the force feed method. The committee reported that no specific recommendation could be made due to the lack of co-operation on the part of the various railroads in furnishing them with experimental data and information. With the tendency in modern locomotive design to increase the thermal efficiency of the boiler by increasing the temperature of superheated steam and the boiler pressure, the question of proper lubrication becomes vitally important. Improper lubrication of cylinders and valves results in a decided increase in maintenance cost. The various lubricants must be tried out to determine the best one to withstand the high temperature of superheated steam. The life of cylinder packing, valves, valve chambers and piston rod packing depends largely on the kind and proper amount of lubricant. Railroad officers should co-operate with the committee and make an exhaustive study of the question of lubrication so that the committee may be able to make specific recommendations as to the most effective and economical way of lubricating the modern steam locomotive.

Systematic Locomotive Maintenance

One of the most annoying and expensive conditions encountered by railroads when handling a heavy traffic movement which calls for utilization of every available locomotive, is the gradual increase in the number of failures of locomotives on the road as the time in the hands of the mechanical department becomes insufficient to keep up closely with the current work reports. These failures disorganize the entire movement, upset the calculations of the dispatcher, increase overtime and cause congestion at terminals. At least one railroad is materially reducing these troubles by a system of systematic inspection and maintenance somewhat similar to that usually followed in the case of electric traction equipment, where the locomotives are held out of service at regular intervals for a thorough inspection and complete maintenance of all parts found to be at all in need of it. The customary steam railroad practice depends largely on engineers' work reports, supplemented by reports of the terminal inspectors, which only bring to attention conditions needing immediate attention to prevent immediate failures. The margin of safety is not high and there is no possibility for advanced planning of his work by the enginehouse foreman. By the regular detention of the locomotives at fixed intervals for the performance of a complete job of running repairs, the work can be laid out in advance, and for a greater part of the time the locomotives are operating with a higher factor of safety with respect to all details than is the case under the customary practice. Systematization tends to decrease the cost of the work and gives a much more flexible sup-

ply of available power for the use of the transportation department. It takes much of the emergency character out of roundhouse work.

Locomotive Design Affects Rail Stress

The influence of low rail stress in reducing rail failures and general track maintenance is undisputed. It is not so generally recognized, however, that the same considerations which bring about low rail stress will often result in reduced stress in certain locomotive parts, thus having a tendency to reduce maintenance-of-equipment costs, as well. The time has apparently passed when locomotive designers can go ahead and increase the size and weight of locomotives without a scientific consideration of the effect on rail stress of such locomotive details as individual wheel loads, wheel spacing, counterbalance, lateral wheel play, type of leading and trailing truck, and other important factors. It has been demonstrated beyond question that actual diagrams of the rail stress caused by different wheel arrangements can be measured, and the locomotive designer can decide with some certainty on the arrangement which will give the best general results. This subject of the relation of track stresses to locomotive design was covered in a comprehensive and striking manner by C. T. Ripley, chief mechanical engineer of the Santa Fe, in a paper presented yesterday. The paper warrants the most careful study by locomotive designers. Many conclusions can be drawn from it, some of which would never be suggested without the proof of their accuracy afforded by the stress diagrams. If the members of the Mechanical Division go home and forget this paper and do not make a study of rail stresses caused by present locomotive equipment, basing future designs on the results of these studies, it will be little short of criminal neglect of a golden opportunity.

Electric Locomotive Development

The paper on electric locomotive development presented to the association yesterday morning by F. H. Shepard, director of heavy traction, Westinghouse Electric & Manufacturing Company, was well received. The paper contains data on all main line electric locomotives in service or under construction in the world, including diagrams of wheel and cab arrangements. All general types of drives are also shown and their respective advantages and disadvantages listed. It will probably surprise many to learn that there are well over two thousand electric locomotives in service in the world. The information contained in the paper is presented in rather simple and elementary fashion, but it is only by doing it this way that a comprehensive picture of the whole situation can be shown. The paper is unusual in that, although it was prepared by a representative of one of the two big electrical companies in this country, it contains about equal amounts of information on locomotives manufactured by both companies and is practically devoid of expressions of opinion. After Mr. Shepard concluded the reading of his paper, W. L. Bean, assistant mechanical manager, New York, New Haven & Hartford, contributed a fund of additional information on electric locomotive operation. J. A. Carmody, superintendent electrical equipment, New York Central, also contributed by describing results obtained with electric locomotives on the New York Central. There was no further discussion, probably because the nature of the paper practically precluded this possibility. The paper as prepared is in character an encyclopedia of electric locomotive development, which lists all locomotives and includes fundamental facts generally accepted by engineers concerning the characteristics of the various types.

Today's Program

The entire day has been set aside by Division V, Mechanical, to view the exhibits.

In addition to the exhibits between the entrance to the Million Dollar Pier and the Convention Hall, there are other features which should not be overlooked. These include, in the words of Secretary Hawthorne's announcement yesterday:

1. The Annex on Arkansas Avenue across from the Boardwalk entrance to the Million Dollar Pier. This exhibit contains about 140 tons of heavy machine tools, all in operation.

2. The exhibition on the outer end of the pier beyond Convention Hall. This contains welding, metal cutting and other equipment not suitable for other exhibit locations because of the fire risk.

3. The Annex around the fish net to the right of the entrance to Convention Hall, containing 21 new and interesting exhibits.

4. The track exhibits on the Philadelphia & Reading tracks on Mississippi Avenue and on the Pennsylvania Railroad tracks on Georgia Avenue; also on the tracks at North Providence Terrace. (These were commented on editorially in Friday's *Daily*.

R. S. M. A. Annual Election

The district elections will be held in the Executive Committee room near the pier entrance from 10:00 a.m. to 11:30 a.m.

The annual meeting of the Railway Supply Manufacturers' Association will be held in the Convention Hall at 12 o'clock noon.

ENTERTAINMENT

10:30 a.m.—Orchestral Concert, Entrance Hall, Million Dollar Pier.

3:30 p.m.—Orchestral Concert and Impromptu Dancing, Entrance Hall, Million Dollar Pier.

9:00 p.m.—Informal Dance. Special Musical Revue, arranged by Tulsa Lee, New York, Ball Room, Million Dollar Pier.

Sunday Program

On Sunday, at 3.30 p. m., a sacred concert will be given in the music room of the Marlborough-Blenheim by the Marlborough-Blenheim orchestra with artists Rass Eriksen, baritone, and Maryrose Walsh, soprano. The program will be augmented by selections given by the orchestra, of which printed programs will be distributed on Sunday.

R. S. M. A. Meeting and District Elections Today

The district elections of members of the executive committee of the R. S. M. A. will be held this morning from 10:00 a. m. to 11:30 a. m. in the Executive Committee room to the right of the entrance to the pier. It will be necessary to elect two members for District 3 and one member each from Districts 4, 5, 6 and 8.

The annual meeting of the Railway Supply Manufacturers' Association will be held in the convention hall at 12 o'clock, noon.

Enrollment

The enrollment booth will be open today from 9:00 a. m. to 12 noon; 2:00 p. m. to 5:00 p. m., and 7:00 p. m. to 9:00 p. m. It will be open tomorrow (Sunday) from 10:00 a. m. to noon; 2:00 p. m. to 4:00 p. m., and 7:00 p. m. to 9:00 p. m.

Motion Pictures of Draft Gear Tests

The Union Draft Gear Company is showing moving pictures at the Club Room, on the 10th floor of the Traymore Hotel, of a number of draft gear tests made under the drop hammer at the company's laboratory at Chicago. The tests compare the action of two spring type gears, one on the anvil and one on the drop, with the action of one spring and one Cardwell gear and of two Cardwell gears, arranged in the same manner, tested to the destruction of the lug rivets. A slow moving picture is also being shown of the closing action of the Cardwell gear.

Registration Figures

At the close of the afternoon registration period yesterday there was a total of 4665 registrations, which is 680 more than for the similar period of any convention since 1911. While there will be no Official List of Enrollment published this morning, we are presenting these figures to show the interest in this particular convention. The registration of railway men is 106 greater than in any previous year since 1911. Below are the figures for the past four conventions:

	1919	1920	1922	1924
Members, Mechanical, A. R. A.	458	666	554	772
Members, Purchases and Stores	....	37	26	21
Special guests	563	285	276	419
Supply men	1900	1935	2015	2300
Railroad ladies	601	413	421	607
Supply ladies	350	649	432	546
Totals	3872	3985	3724	4665

Illumination of Capt. Young's Villa

The Pyle-National Company is making an especially attractive display of the capacity of its floor-lighting system, ordinarily employed for the illumination of railroad yards, etc., by lighting the beach and Capt. Young's villa on the pier by the use of a powerful light and special reflector. The reflector used for beach lighting was originally designed for use on airplanes in the mail service though it is of the same general type as used in railroad yards. The lens used for the illumination of Capt. Young's villa was originally developed for the State Railways of India where a particularly wide spread of light is required for lighting the whole right-of-way. This is necessary because of the habit elephants and other animals have of avoiding flies and other insects of the jungle by straying on the right-of-way. Hence this particular type of lens has come to us known as the "Elephant" lens. It is 14 in. in diameter while the one used for illuminating the beach is 24 in. It is of interest to note that this illumination has proved so attractive a feature to visitors that it has been arranged to make it a permanent feature and provision has been made for eight projectors with suitable lenses.

Lost and Found

Lost—Badges 6887 and 3723. The finders of the badges will kindly return them to the Enrollment Booth, which is located at the main entrance of the pier.

Lost—Somewhere in the vicinity of Booth 8, a small gold bead hand bag containing vanity box and trunk key. Return, if found, to the *Daily Railway Age*, Booth 1.

Lost—A Phi Beta Kappa key watch charm. Return, if found, to A. E. Preble, track supervisor, Pennsylvania Railroad, Paoli, Pa.

Lost—One dark blue glass earring. Return, if found, to the *Daily Railway Age* booth.

Found—A brown fur neck piece. Owner can have same by identifying, at the booth of the *Daily Railway Age*, Space 1.

Found—A rain coat in the meeting hall. Can be secured at the office of the Secretary of the R. S. M. A.

Professor Talbot's Discussion of Mr. Ripley's Paper

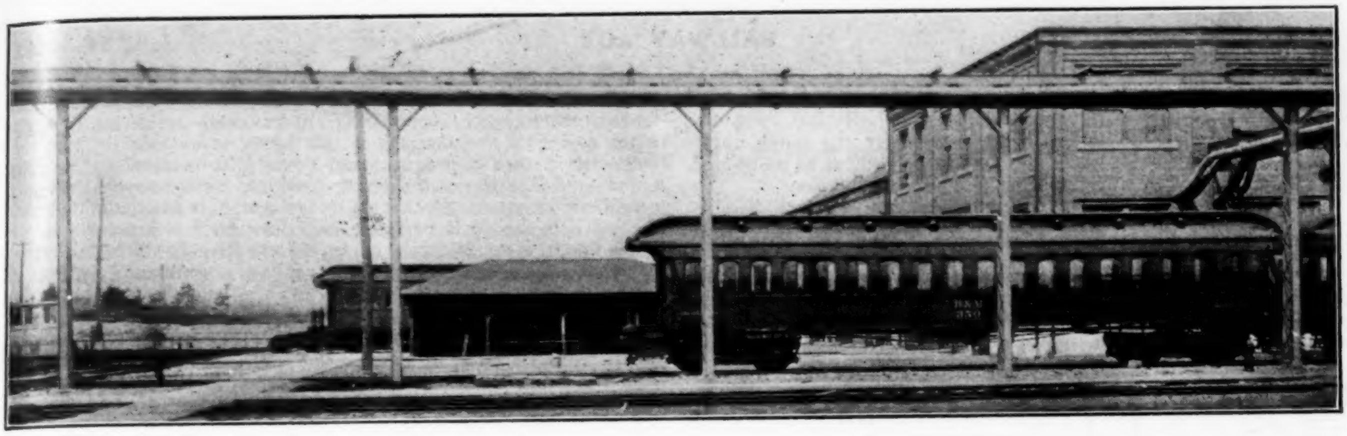
Because of a misunderstanding the discussion by Professor R. A. Talbot, University of Illinois, of Mr. Ripley's paper on "Stresses in Track Produced by Modern Locomotives," was detached from the report and reached the printshop too late to be included in its regular position in the proceedings. Professor Talbot's discussion follows:

The very high pressures on the inner rail under one of the driving wheels which may be developed at low or medium speeds, pressures which are far greater than the nominal wheel load, are especially worth consideration. These high pressures are found not only on 10 deg. curves but also on curves of medium curvature. The results of the tests reported in the paper and of other tests warrant the statement that the relation between locomotive design and track stresses needs further experimentation and fuller consideration.

The stresses in the rail throw light on other track effects. These stresses in a sense are representative of the effect of the locomotive upon track maintenance, such as alignment, surface, tie wear, ballast condition, and other items of upkeep. In a way, a reduction in stresses, particularly in the lateral bending stresses and lateral pressures, means a reduction in maintenance charges and also in the chances for accidents through imperfect track conditions.

It seems reasonable to believe, that the conditions which produce undue stresses in the rail, both the longitudinal and the lateral stresses, and the resulting effects in the ties and ballast, produce similar strains and stresses in the locomotive wheel frames, connections and other parts. It seems to be true that some or many of the stresses in the locomotive are unnecessarily high and that in many cases some changes in design would result in a reduction in cost of upkeep. There are opportunities for advantageous changes to be made in the design of springs and equalizing levers.

Experience for 10 years in track tests shows that with proper care and use the stremmatograph is a trustworthy means of determining the stresses in the rail under the action of the locomotive in running over the track. It may be shown that the wheel loads of locomotives and cars found by means of stremmatograph records and other data of the track correspond very closely with the actual wheel loads and not the nominal loads. It may be seen also that the action of the locomotive and track is not the same on different runs. In particular, the locomotive in motion, its position with respect to the track, both vertically and transversely, the position of the springs, bearings, and flanges, the up-and-down and side motion, all go to produce variations in effect, and so necessarily some stresses will be much greater than others.



Section of the Billerica, Mass., Shops of the Boston & Maine.

American Railway Association—Division V

Papers by C. T. Ripley and F. H. Shepard; Reports on Lighting; Electric Rolling Stock

THE MEETING of Division V—Mechanical, American Railroad Association, was called to order promptly at 9:30 a.m. yesterday morning by Chairman Purcell.

Before taking up the regular program Secretary Hawthorne called special attention to certain features of the exhibit which are off the beaten track between the Boardwalk and the Convention Hall and which might be overlooked. These include the Machinery Hall Annex at the end of Arkansas Avenue across the Boardwalk from the Million Dollar Pier; the exhibit just beyond the Convention Hall which contains the welding, metal cutting and furnace equipment; the annex to the right of the entrance to the Convention Hall which is being used for the first time this year and contains 21 exhibits; the track exhibits on the Philadelphia & Reading tracks, Mississippi Avenue; and the Pennsylvania Railroad tracks on Georgia Avenue. These parts of the exhibit contain so many new and novel features that they should not be overlooked by the convention attendants.

Relation of Track Stress to Locomotive Design

By C. T. Ripley
Chief Mechanical Engineer, A. T. & S. F.

In this paper the author first sketches the history of the study of track stresses which has been conducted largelv from the point of view of the civil engineer. He then suggests that the mechanical engineer in the design of equipment—particularly locomotives with their present-day wheel loads—has a responsibility in the matter of track stresses to which he should give attention, and which may require additional tests to determine the effect of wheel arrangements and loadings on rail stresses. He describes the stremmatograph and its use in measuring rail stresses and gives the results of a number of tests which have been run on the A. T. & S. F., of which road Mr. Ripley is chief mechanical engineer. The paper directs attention to a matter which demands constructive attention from the Mechanical Division.

C. T. Ripley

The failure of rails has engaged the attention of metallurgists and civil engineers for many years. Their studies have undoubtedly resulted in a great betterment of conditions, but the size and weight of locomotives and cars have increased at such a rate that it has been practically impossible for the strength of the track structure to keep pace, and rail failures are still a very serious problem for the railroads of this country. The designers of locomotives have attempted to do their part by holding down the weight of reciprocating parts and thus reduce the dynamic augment produced by the overbalance in drivers. Unfortunately, however, very little test

data have been available as to what stresses were produced in the rails under locomotives of various designs. Theoretical computations and empirical deductions were necessarily the guide as to how to distribute the load over the various drivers, as to the use of flangeless tires, as to wheel spacing and similar questions.

Mechanical Engineers Must not "Pass the Buck"

During the last nine years the maintenance engineers, through their committee on track stresses, have started a study of the subject which is producing data which the mechanical engineers can use in the consideration of the various details of locomotive design.

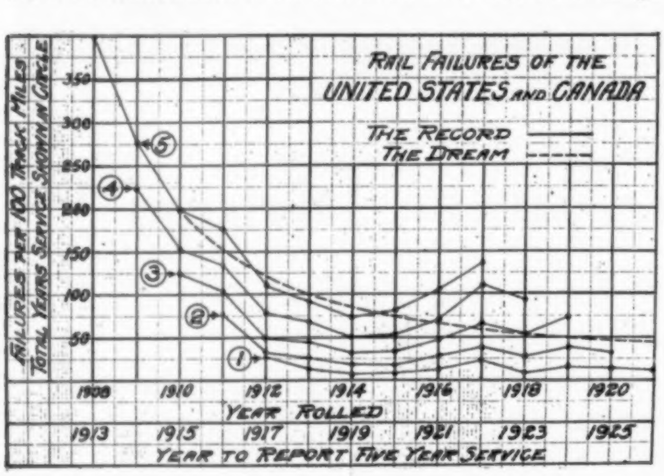
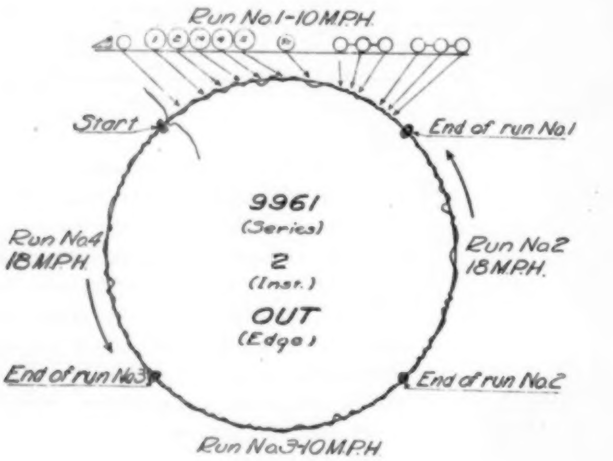


Fig. 1—Accumulated Rail Failures per 100 Miles of Track

It is readily acknowledged that the railroads cannot go backward by reducing the size of their locomotives, as economic conditions prohibit such action. However, it is not proper for the mechanical engineers to "pass the buck" to their maintenance of way departments by saying that it is up to them to build a track structure which is able to carry the load. The maintenance engineers should be and are doing everything in their power to improve the track structure, both by heavier and better rail, but the problem is really a joint one and locomotive designers should exert every effort to make their designs of such a nature that the track stresses produced are as low as possible. To do this, they should make use



Stress Circle ½ to ¾ in. Diameter.

Fig. 2—Typical Stremmatograph Disk Showing the Relation of the Zero Circle and the Strain Record and the Relation of the Different Wheels to the Strain Curve—The Blur at the End of Each Run is Caused by Backing the Train and Locomotive Over the Instruments, the Needle Touching the Surface but without Rotating the Disk and Thus Having All Records Superimposed

of all the valuable data which have been accumulated by the American Railway Engineering Association Committee which have been published in three bulletins, one in 1918, one in 1920 and one in 1922. To supplement this and apply it to the locomotive design problems of individual railroads, it will probably be necessary to make further tests. Such a program has been carried out on some roads and it is the purpose of this paper to explain the methods followed in such a program and the results secured. It is fully understood that the results here secured may not be applicable under conditions existing on other railroads and it is also admitted that the work is far from complete, but the record is presented in the hope that the results may be least indicative of the possibilities of such work and help others outline a similar program of investigation.

In order to bring to your attention the importance of this question of rail failures, it may be well to quote some figures from "Rail Failure Statistics" presented in the bulletin of the American Railway Engineering Association of January, 1924.

The following tabulation shows the rollings for 1917 and succeeding years, giving the tonnage and track miles, as embodied in these statistics:

Year Rolled	Tons	Track Miles
1917	1,050,632	6945.43
1918	917,050	6117.93
1919	947,577	6402.43
1920	1,146,419	7550.63
1921	1,138,048	7421.29
1922	808,128	5130.65

Fig. 1 shows diagrammatically the accumulated failures per hundred track miles for designated service of rail ranging from one to five years. It also indicates the achievements which have been made in the betterment of rails as well as the setback caused by the war conditions. The increase in failures begins with the 1915 rollings, and judging from the trend of the curves, we will not obtain a

Fig. 3—Stremmatograph Unit Comprising Head Piece, Tail Piece and Needle Bars All Set on the Under Side of a Piece of Plate Glass of the Same Width as a 90-Lb. Rail Base to Show the Relation in Service—The Disk at the Right Is Adjusted to the Needle Point for Record; the Disk Holder at the Left Is Thrown Back for Removal of the Disk

downward trend until after the 1919 rollings.

The first recorded attempts to measure track stresses in this country were made by Dr. Dudley of the New York Central, who devised an apparatus for this purpose. The results of his work are given in the 1913 Proceedings of the American Railway Engineering Association and show data obtained subsequent to 1900. In the year 1913, The American Railway Engineering Association appointed a committee with Prof. A. N. Talbot as chairman, to devise apparatus and make a complete study of the subject. This committee was given authority to co-operate with a similar committee of the American Society of Civil Engineers, appointed about the same time. This problem was a very large one and the first report of this committee was not issued until 1918. The committee has made tests on ten different railroads.

Stremmatograph Measures Rail Stress

The apparatus used is called a stremmatograph. This is essentially a device for measuring the strain (stretch or shortening) in a 4-in. length of the base of the rail. This movement is recorded on a smoked glass disc by using a phonograph needle, and as the magnitude of the needle movement is, of course, very small, the record

must be magnified for reading. This is done by putting the disc under a binocular microscope with a micrometer eyepiece giving 75 diameter magnification. These readings are converted into terms of stress in pounds per square inch by the use of a constant, which takes into account the location of the instrument with reference to the neutral axis, of the rail, the modulus of elasticity of the rail steel, using 30,000,000 (assuming that the steel is working within the elastic limit curve where the stress is proportional to the strain) and the gage length 4 in. The discs are rotated as the locomotive passes over them in order to separate the stresses for the individual wheels. Before any record is made, the disc is turned a full revolution in order to establish a zero circle or base line from which the deflections are measured. One disc will usually carry the record

Fig. 4—Track Stress Test Instruments Showing Connection to Master Shaft, All Instruments Uncovered for Removal and Adjustment of Disks—The Hand-Driven Worm Gear Is Connected to the Main Shaft by Means of Universal Joints to Permit Easy Alinement

for four runs as one-quarter of the circle is sufficient for recording all the wheels of a locomotive and tender. A typical disc is represented in Fig. 2, with relative location of locomotive and tender wheels. The deflection inside the circle are tension strains in the rail base produced under wheels, and those to the outside of the circle are compression strains produced between wheels.

Eight instruments, each having two separate sets of recording units including carriages, discs and needle bars, are used. This arrangement gives four records on the outside edge and four on the inside edge of each rail, directly opposite to each other, or 16 sets of readings per run. The location of instruments is necessarily between the ties, and the distance between the instruments is taken as nearly equal to the driver spacing as the location of ties will permit. The entire set of discs for all the instuments is driven through a series of gears and drive rods from a single hand wheel. The gear ratio is 75 to one. Figs. 3 and 4 show the instruments, location, and method of operation. The rail is marked in one-foot lengths and a mark put on the tire at the centre of the counterweight, so that from observation as the locomotive passes the marked sections, record can be had of the counterbalance location. A speedometer is applied to the locomotive to obtain and record exact speed and make duplicate tests possible. A number of runs are made at predetermined speeds and records are thus available for various positions of the counterbalance at different speeds, as there is enough slip in starting and stopping to give the various locations of counterbalance.

The tests made on the Santa Fe in 1921, under the direction of the American Railway Engineering Association Committee and tests made in 1922, 1923 and 1924 under the direction of the engineer of tests, included Mountain type, Pacific type, balanced compound Prairie, and both light and heavy Santa Fe type locomotives. Figs. 5, 6 and 7 show the results of tests of the different types of locomotives on tangent track and Figs. 8 and 9 show results on 10-degree curve.

The first series of stress data obtained on the Santa Fe indicated the desirability of further study of the design of the heavy Santa Fe type of locomotives, as the stresses under the fourth driver on the outside edge of the low rail on heavy curves and under the first driver on the outside edge of the high rail were very high, as shown in Fig 8. The stresses under the trailer on tangent track were also high.

Rail Stresses on Curved Track

In the third American Railway Engineering Association progress report, the question of rounding curves and resulting stresses is discussed in detail, and will not be repeated here, but attention is called to the analysis showing that different types of locomotives and dif-

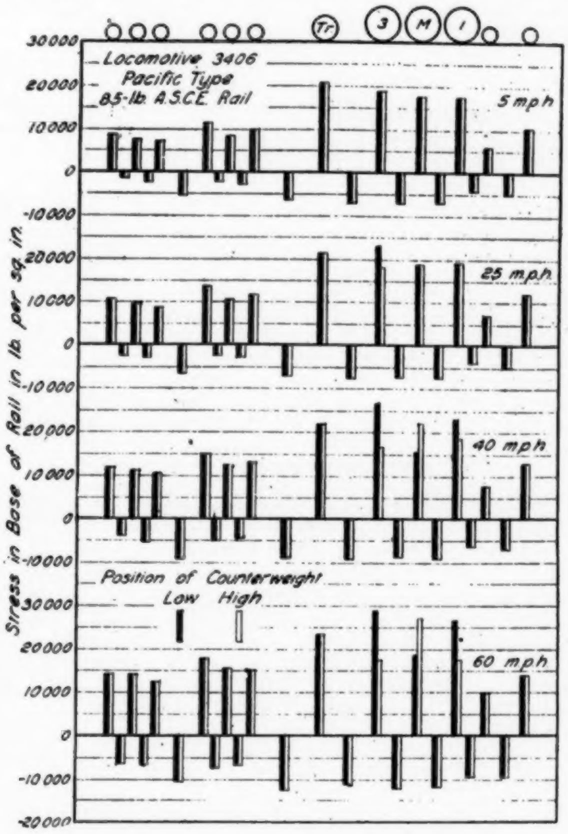


Fig. 5—Stress in Rail on Straight Track at High and Low Position of Counterweight, Pacific Type Locomotive

ferent designs of the same type, exert very different stresses on the rail; also, that the pivoting action differs. The pivot may be directly under wheels in one case and between wheels in another, as shown by Fig.10 taken from that report and the maximum of

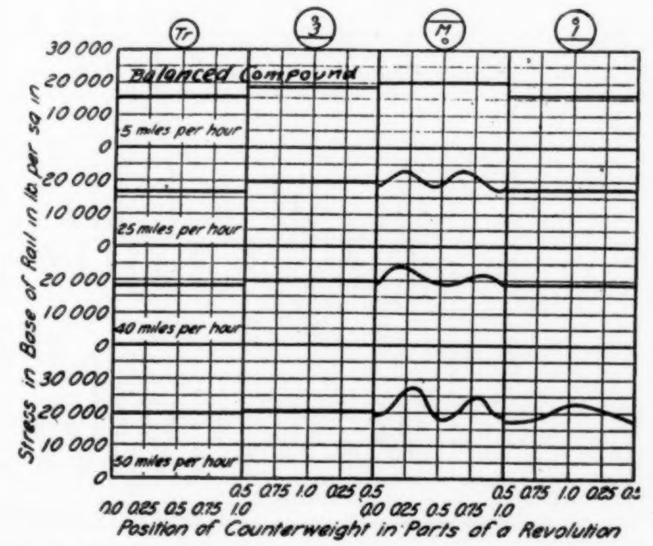


Fig. 6—Curves of Average Stress in Rail on Straight Track Throughout Revolution of Drivers, Balanced Compound Prairie Type Locomotive

all stresses occur at the pivot point on the inside rail. It is also pointed out that the surface friction between tire and rail may produce this high stress and it is not necessary that the wheel flange be in contact with the rail head. In fact it is not uncommon for this

surface friction to induce an inward bending moment on the rail. By the same analysis, it is evident that the rail stresses are affected by the lateral motion between box and wheel hub, and also by the wheel spacings in relation to each other. If, for example, in rounding a curve the first pair of drivers exerts an excessive stress in the high rail and the second pair a low stress, then by increasing the lateral of the first pair of drivers either between the hub and box or by decreasing the tire spacing on the wheel

Fig. 7—Curves of Average Stress in Rail on Straight Track Throughout Revolution of Driver, Light Santa Fe Type Locomotive

centers, there will be a tendency to equalize the stresses, permitting the first pair of drivers to take less and the second pair more of the turning load. But, in any such change there are so many variables involved that an intelligent analysis is difficult and hence the field for the practical application of the stemmatograph to determine the stresses under the various conditions.

As the rigidity of the frame has a tendency to cause high stresses to be exerted by the front drivers in rounding curves, or actually the Delta trailer truck, flange oilers, and the Franklin lateral motion device on the front pair of drivers are all measures that have been employed to reduce the stresses exerted on the rail.

Heavy Santa Fe Type Locomotives Tested

In order to demonstrate just what results could be secured by applying the above theories, several heavy Santa Fe type locomo-

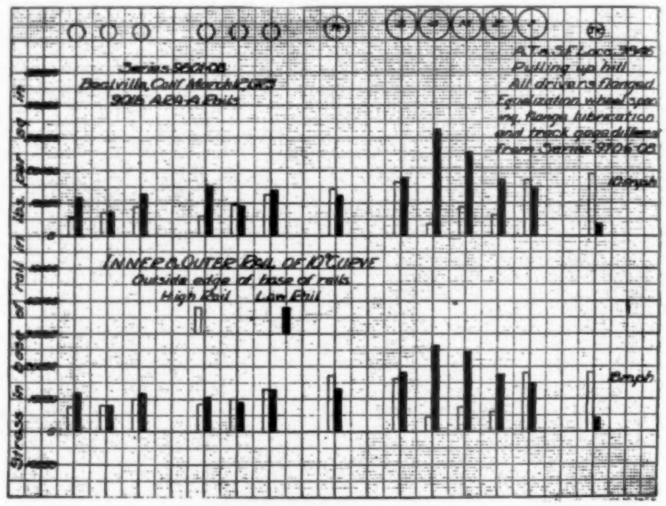


Fig. 9—Stress at the Outside Edge of the Base of the Inner and Outer Rails of 10-Deg. Curve, Heavy Santa Fe Type Locomotive 3846—All Drivers Flanged

tives were tested with various combinations of flanged and unflanged tires. It was proven that the best arrangement was with all tires flanged making the third and fourth drivers divide the excess strains in the low rail. The equalization was also changed so

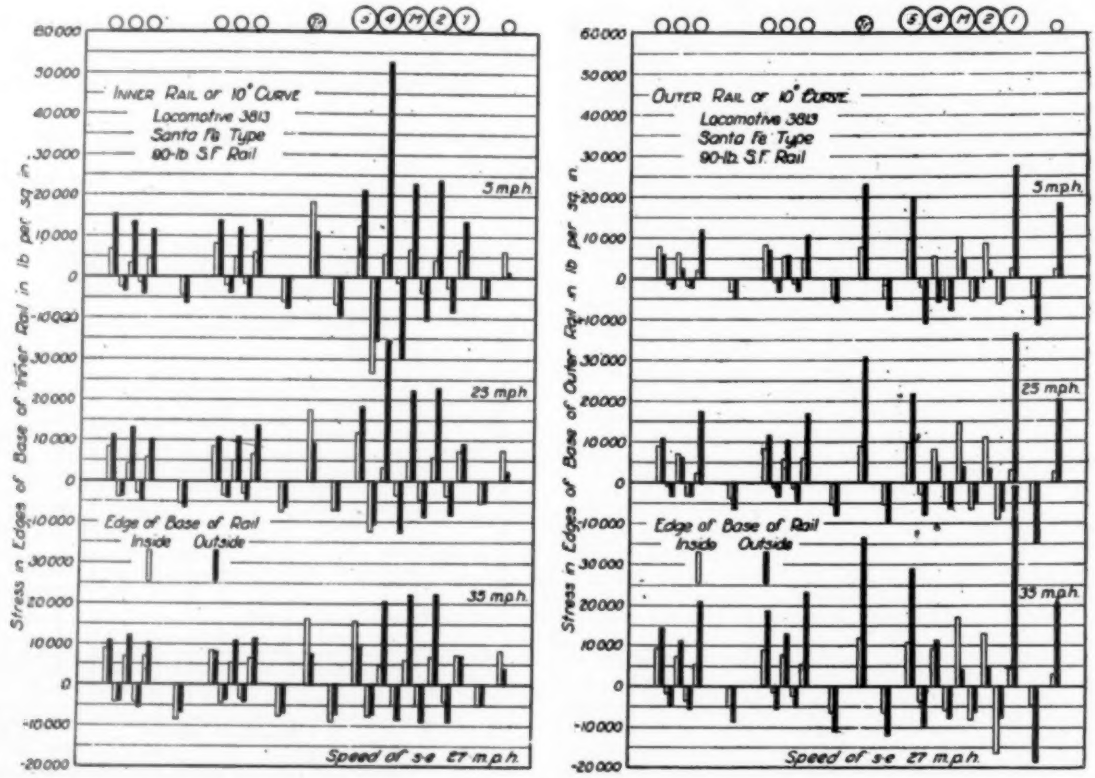


Fig. 8—Stress at the Inside and Outside Edges of the Base of the Inner and Outer Rails of 10-Deg. Curve, Ribera, N. M., Heavy Santa Fe Type Locomotive No. 3813

tends to straighten out curves, there are, of course, similarly high stresses set up in locomotive frames. The trailer may also exert high stresses partly due to rigidity and partly to the long space between the last driver and the trailer. The double trailer truck, as to concentrate the load on the main drivers in an attempt to reduce the stresses under the front and rear drivers. Fig. 9 shows the results. The original intermediate and final equalization of weight and condition of tires are shown in Tables I and II, which

also refer to the respective stress diagrams obtained to any particular condition, and this table shows the radical improvements already referred to in the diagrams.

During the past year, a series of stremmatograph tests have been made on the large electric locomotives used on one of our Western railways, by the committee of the American Railway Engineering Association. The designers of electric locomotives generally claim that these locomotives are easier on track than steam locomotives, basing their conclusions on the absence of reciprocating parts and lower individual wheel loads. The final calculations of the above mentioned tests are not yet in shape for presentation, but the preliminary figures indicate that these electric locomotives do produce lower rail stress than the steam locomotives, particularly on tangent track at high speeds. On 10-degree curves, however, some readings as high as 50,000 lb. sq. in. have been developed in the edge of the base of 90 lb. rail. This indicates that designers of electric locomotives should also make careful study of pivoting action on sharp curves, as it will probably be found that these maximum stresses can be reduced just as they have been on Santa Fe type steam locomotives.

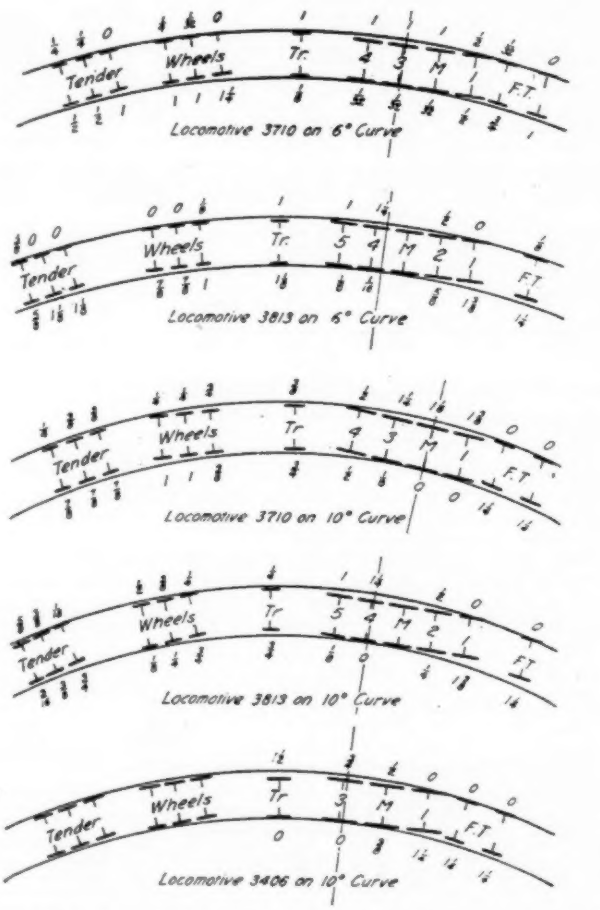


Fig. 10—Relative Position of Wheels of Locomotives and Tenders with Respect to the Rails of Curved Track

A number of new locomotive designs are being developed which it is claimed will increase the power of the locomotive without increase in weight on drivers, which is, of course desirable from a track stress veiwpoint. As examples of these developments, I might mention the three cylinder locomotive. All of these types are being actively developed and give promise of accomplishing the results claimed for them.

Up to the present time, practically no stremmatograph studies have been made to determine stresses under heavy, loaded cars. Indications are that stresses are high enough to warrant the careful consideration of car design, particularly as regards the use of four and six wheel trucks. Some figures of this kind will be available in the near future.

Most motive power officials have at some time had experience with cases of kinked rails developed by certain locomotives. These could usually be traced to stuck wedges, or to the operation of poorly counterbalanced locomotives at excessive speeds. It is not the purpose of this paper to discuss this phase of the subject, but attention is called to the fact that inasmuch as the stresses produced in the rail by modern locomotives in the best of condition are high, it is highly important that any maintenance features which tend to increase the stress should be closely watched and every effort made to eliminate them.

Rail Stress Due to Overbalance

In considering the stresses produced by locomotives, we cannot overlook the stress produced by overbalance due to partial balance of reciprocating parts and to the fact that the forces are acting in different planes. One of the most interesting points in these stress diagrams is the effect of counterbalance. By using the standard centrifugal force formulae we can calculate the theoretical vertical blow or dynamic augment due to the overbalance in each driving wheel. The stress records check these calculations fairly well for all wheels except the main, but here it will be noted an underbalance is always recorded instead of the supposed overbalance; that is, the blow on the rail occurs when the counterbalance is up. This is a condition which calls for careful consideration by locomotive designers. In the 1917 report of the Master Mechanics Association Committee on counterbalancing, it was recommended that no allowance should be made for the difference in plane of the counterbalance and the revolving parts as the resulting discrepancies were small. This was probably true for small locomotives, but in modern heavy power the weight of the parts as well as the difference in plane has increased to such an extent that allowance should be made. It will be noted from Tables III and IV that the lack of allowance for difference of plane results in the counterbalance for the main wheels being too small even to balance the revolving parts, let alone the reciprocating parts. This is a very undesirable condition from every viewpoint. It undoubtedly results in heavier maintenance charges due to harder service on tires, boxes, rods, pins, and brasses and is the probable explanation of some of the irregular tire wear conditions which are now being found on large locomotives. Enough counterbalance weight should be added at least to fully balance the revolving parts and this would produce a stress diagram which would show a straight line for the main driver. Unfortunately in large freight engines with their small drivers there is not always sufficient room in the main wheel centers to add this needed counterbalance. Inside bobs are one form of solution, but they are undesirable features and very large weights are necessary due to relative ineffectiveness of weight at this location. Cross counterbalancing is another line of attack on this problem which would undoubtedly be helpful. Putting the extra weight in the other drivers is not desirable as it increases the blow under these wheels and also increases the punishment of middle connection brass. In many types of locomotives, the extra weight can be added to the main driver and this should be done. An example of a poorly balanced locomotive is shown in Fig. 7. In this locomotive the drivers are so small in diameter that it is impossible to get sufficient counterbalance even with the inside bobs.

"Balanced" Compound Not Perfectly Balanced

Fig. 6 for balanced compound engine is of interest, as it shows that the theory that this type is perfectly balanced is incorrect. There is a hammer blow at two points midway between the pin and the counterbalance. The resulting effect, however, is not of serious consequence. All of the locomotives tested except the old light Santa Fe type referred to show reasonable track effects due to counterbalance. The average dynamic augment at rated speed is about 35 per cent of the static load. However, the total stress in rail is so high that it is quite important to do everything possible to lighten the weight of reciprocating parts and locomotive designers should continue their efforts along this line.

The diagrams showing tests on straight track indicate the increase in stress with increase in speed even under truck wheels where counterbalance plays no part. The effect of the distance between wheels is also shown. Where there is a long space, such as between the last drivers and the trailer, there is an increase in the stress. This latter condition makes the loads on trailers a feature which must be given careful consideration. Trailer wheels on large modern locomotives produce stresses as high as those under the drivers at high speeds. The only remedy in view of the continually increasing weight at the rear end of locomotives due to such devices as stokers, syphons, flexible bolts, etc., is the use of the 4-wheel trailer truck.

Results of Changes in Heavy Santa Fe Engines

In conclusion, special attention is called to the progress resulting from changes on heavy Santa Fe type locomotives. The old standare arrangement was to have the main drivers blind, all others flanged and a fairly uniform distribution of weight between the different drivers. The first series of tests made on and near the

horseshoe curve in New Mexico on tangent track and 6-deg. and 10-deg. curves, showed that some high stresses were obtained under these locomotives, especially on 10-deg. curves. After the compilation of this information, both the mechanical and civil engineering departments took steps to equalize and reduce the stresses. The mechanical department considered the need and possibilities of main driver tire blind, fourth driver tire blind, main and fourth blind; also, conditions with and without flange oiling. As a result of this series of tests, the standard practice was changed to use all drivers flanged on Santa Fe type locomotives. In the fourth series of tests, made in January, February, and March, 1924, special attention was paid to the effect of the lateral motion

TABLE I—AXLE LOADS OF DIFFERENT TYPES OF A. T. & S. F. LOCOMOTIVES

Loco. No.	Weight distribution	Tender Axle load on rails, lb.	Locomotive Axle Load on Rails, lb.								Stress Diagrams shown in Figures	Type of Locomotive
		(4) (3) (2) (1)	Tr	3	M	1	Tk					
1630	A	164,500	42,200	58,400	57,700	58,600	31,300				27	Prairie Balance Compound
		(6) (5) (4) (3) (2) (1)	Tr	3	M	1	Tk	Tk				
3406	B	233 700	60 800	61 400	58 400	59 800	60,600				23-32	Pacific
		(6) (5) (4) (3) (2) (1)	Tr	4	3	M	1	Tk	Tk			
3710	C	233 700	66 500	60 400	60 500	60 800	61 400	58,100			22-28-31	Mountain
3709	D	242 400	50 500	60 350	60 550	60 850	61 350	58 100			37	Mountain
3709	E	242 400	52 400	57 700	58 400	64 800	60 400	58 000			38	Mountain
3741*	F	236 600	50 900	61 100	59 800	62 220	59 300	61 900			39	Mountain
		(6) (5) (4) (3) (2) (1)	Tr	5	4	M	2	1	Tk			
1702	G	185 400	26 200	50 300	49 100	56 500	49 600	52 800	27 500		24-29	** Santa Fe
3813	H	277 000	61 500	63 900	62 500	62 900	59 600	60 400	25 800		25-30-33	Santa Fe
3832	I	293 800	45 800	60 800	60 900	60 400	60 400	59 700	27 400		49-35-36-42-44	Santa Fe
3846	J	293 800	52 400	60 500	60 000	59 200	58 000	59 200	31 700		43-45-46-49	Santa Fe
3846	K	293 800	53 150	57 640	57 880	64 900	62 860	54 170	30 400		40-47	Santa Fe
3832#	L	293 800	45 800	57 900	57 900	65 100	63 300	54 400	31 000		48	Santa Fe
3855*	M	293 600	52 800	61 500	63 600	64 800	61 800	59 800	33 300		41	Santa Fe
		(6) (5) (4) (3) (2) (1)	Tr	Tr	5	4	M	2	1	Tk		
3829*	N	277 000	74 500		56 200	54 500	58 000	59 700	61 000	32 100	26-34	Santa Fe

* Delta Trailer truck, Locomotives 3741 and 3855, four wheel trailer truck Locomotive 3829, other locomotives Hodges trailer truck.

\# Franklin Lateral Motion Device, front drivers. ** Santa Fe Light, all others Heavy Type Santa Fe.

changes in the locomotives and the civil engineering department co-operated in making 8-deg. the maximum curve in new construction. Arrangements were made to run additional tests to see what changes could be made in these locomotives to reduce the high stresses. A series of runs were made near San Bernardino, California, using a different locomotive from that in New Mexico, but in the same condition as to tire arrangement and then the device on the front pair of drivers on the Santa Fe type and the effect of the two kinds of trailer trucks on both Santa Fe and Mountain types of locomotives.

The next set of experiments which will be made will be with a heavy Santa Fe type locomotive, which is now being constructed with a different counterbalance. It is thought that by a change in the counterbalance it will be possible to overcome the unde-

TABLE II—FIBRE STRESS IN OUTER EDGE OF BASE OF LOW RAIL OF 10 DEG. CURVE AT SPEED OF 10 M. P. H.

Loco. No.	Weight distribution	Drivers	Fiber Stress in Rail Edge - lb. per sq. in.														Stress Diagrams shown in Figures	Test Place	Test Date
			6	5	4	3	2	1	Tr	4	3	M	1	Tk	Tk				
3710	C	All flanged	10,500	10,000	8,000	11,000	9,500	10,000	16,000	20,500	*46,500	35,500	21,500	-500	4,500		31	Ribera	9-19-20
3709	D	All flanged	9 200	5 400	8 000	11 300	7 800	10 600	10 600	13 800	*37 800	24 200	17 300	3 600	8 700		37	Cajon	2-24-24
3709	E	All flanged	9 500	7 500	8 400	10 800	7 400	11 200	9 000	12 700	*37 800	23 200	14 800	2 500	6 500		38	Cajon	3- 2-24
3741#	F	All flanged	8 800	5 000	6 600	6 800	6 700	8 300	11 200	14 500	*31 200	28 400	16 600	3 300	7 800		39	Cajon	2-14-24
			6	5	4	3	2	1	Tr	5	4	M	2	1	Tk				
3813	H	Main blind	15 500	13 000	11 500	13 500	12 000	14 000	11 500	11 500	*52 500	23 000	23 500	13 500	1 800		33	Ribera	9-21-20
3832	I	Main blind	14 000	15 000	13 000	17 000	14 500	16 000	12 000	15 000	*54 500	24 000	22 000	18 000	3 500		35-42-49	Bealville	4-11-22
3832	I	M&4th blind	12 500	13 300	10 300	16 000	15 500	9 400	15 300	*57 300	6 500	27 000	34 000	24 000	6 500		36-44	Cajon	4-20-22
3846	J	4th blind	16 500	13 000	20 500	17 000	17 100	23 600	12 500	26 000	11 000	*64 600	26 200	17 500	6 200		43	Cajon	2- 9-23
3846	J	2M blind	8 800	6 000	10 600	9 600	9 200	15 200	6 300	*58 000	4 700	10 700	9 500	26 500	5 000		45	Cajon	2- 6-23
3846	J	All flanged	16 800	10 800	18 000	16 700	16 000	23 200	17 000	22 500	*49 000	33 200	28 800	17 500	5 500		46	Cajon	2- 2-23
3846	K	All flanged	11 500	7 400	12 800	15 300	9 200	14 000	12 500	18 000	*32 500	25 600	17 200	14 400	3 500		40-47	Bealville	3-12-23
3832**	L	All flanged	7 000	9 500	12 000	8 600	7 300	13 300	7 600	13 700	26 300	*35 500	11 300	11 000	6 000		48	Cajon	2- 1-24
3855#	M	All flanged	6 600	6 700	10 400	8 400	7 000	11 400	12 700	12 000	*35 500	20 400	12 000	14 000	4 800		41	Cajon	2- 8-24
			6	5	4	3	2	1	Tr	Tr	5	4	M	2	1	Tk			
3829#	N	Main blind	13 500	9 500	12 500	16 000	11 500	13 500	10,000	14,500	5 500	*48 000	26 000	26 500	23 000	4 000	37	Ribera	9-19-20

* Maximum Stresses under wheel marked. # Delta Trailer Truck on Locomotives 3741 and 3855, four wheel trailer Locomotive 3829.

** Franklin Lateral Motion Device, front drivers.

tests were repeated having both the main and fourth drivers blind, and also with the tire tread of standard contour and with a groove in the tread, such as exists in badly worn tread tires.

In the third series, tests were made with all tires flanged, using different tire spacings all within standard limits; then with the sirable conditions indicated in previous tests. The main wheels are to be counterbalanced, including cross balance, making allowance for differences in planes. There will also be additional counterbalance added to the other driving wheels, in order to secure a better balance of reciprocating parts. This extra coun-

terbalance will be added to the mate wheel in each case rather than to the individual wheel being balanced, in order to avoid undue increase in dynamic augment.

Some criticism of stremmatograph tests has been made on the

TABLE III

Weights of Rotating and Reciprocating Parts, in Pounds—Mountain Type Locomotive of the A. T. & S. F. Ry.

RECIPROCATING PARTS

Piston	904
Crosshead	610
Union link and lower end of combination lever	62
40% main rod, weight on crosshead pin	522
	2098

$$\frac{.50 \times 2098}{4} = 262$$

ROTATING PARTS

Driver Number	4	3	Main	1
50% of weight of reciprocating parts	262	262	262	262
Main rod, weight on crank pin	......	......	783	......
Side rod, weight on crank pin	180	530	665	175
Crank pin	135	130	430	100
Crank pin hub	129	129	266	129
One-half eccentric crank	......	......	87	......
Total	706	1051	2493	666
Equivalent weight required at center of counterweight	417	640	1939	417
Weight used	417	640	1939	417
Difference between weight required and weight obtained	0	0	0	0
Equivalent difference at crank pin circle	0	0	0	0
Overbalance or underbalance at crank pin circle for rotating parts only	+262	+262	+262*	+262

*If the effect of the rods and pin not being in the plane of the counterweight is calculated by the method given in the second progress report, this becomes approximately an underbalance of 35 lb.

ground that the results are so variable that the measurements are not reliable. It is admitted that the results of individual readings do show wide variations, but there are also marked differences in conditions, and the presence of a number of very high

TABLE IV

Weights of Rotating and Reciprocating Parts, in Pounds—Heavy Santa Fe Type Locomotives of the A. T. & S. F. Ry.

RECIPROCATING PARTS

Piston	1070
Crosshead	705
Union link and lower end of combination lever	62
40% main rod, weight on crosshead pin	585
	2422

$$\frac{.50 \times 2422}{4} = 303$$

It was not possible to counterbalance for the whole of the rotating weight in the main wheel; the deficiency of 21 lb. was distributed equally among the other drivers, bringing their total up to 308 lb.

ROTATING PARTS

Driver Number	5	4	Main	2	1
50% of weight of reciprocating parts	308	308	......	308	308
Main rod, weight on crank pin	......	......	877	......	......
Side rod, weight on crank pin	172	493	785	454	166
Crank pin	118	130	500	130	105
Crank pin hub	144	144	271	144	144
One-half eccentric crank	......	......	91	......	......
Total	742	1075	2524	1036	723
Equivalent weight required at center of counterweight	574	899	2714	866	564
Weight used	574	899	2693	866	564
Difference between weight required and weight obtained	......	......	21	......	......
Equivalent difference at crank pin circle	......	......	20	......	......
Overbalance or underbalance at crank pin circle for rotating parts only	+308	+308	−20*	+308	+308

*If the effect of the rods and pin not being in the plane of the counterweight is calculated by the method given in the second progress report, this becomes approximately an underbalance of 360 lb.

stresses does not so much discredit the means of measurement as it shows the need for attention to reduce these stresses.

Both Track and Locomotive Maintenance Costs May Be Reduced

The desirability of low rail stresses as an aid to track maintenance and safety is generally conceded and it has been pointed out how apparently small details in locomotive construction affect the track stresses produced. Representative stress diagrams, the results of numerous tests have been shown and the marked changes of these diagrams with changes of locomotive condition are strong arguments in favor of the practicable application of track stress measurements as an aid to track maintenance and the improvement of locomotive design. Furthermore, reduction in rail stress will result in corresponding reduction in stresses in certain locomotive parts and therefore the locomotive designer by giving consideration to this question will not only reduce track maintenance costs but also locomotive maintenance costs.

Discussion

H. A. Houston (Westinghouse Electric & Manufacturing Company): Mr. Ripley speaks of changing the lateral on the driving axles. In doing so he must accept the fact that his lever arm is decreased for turning his locomotive, and therefore his flange pressure must be increased. The increase of these forces is a condition which results in excessive track stress.

An analysis of the force acting on a locomotive can be made for static adjustment in a curve which may be considered at any speed below forty miles per hour. This is a part of the design of electrical locomotives by the company with which I am associated.

The analysis of locomotives in the design stage not alone embraces curving characteristics but the flange pressures of the various wheels, their action on curve and tangent; also the relative action of the guiding and trailing trucks in assisting that locomotive around the curves.

Not alone do we consider the pivoting action of electric locomotives on curves, but we also study the effect of piling up tractive force and this is generally on pusher locomotives. This concentration of tractive effort further involves a study of the connection between the motive power units and the effect on the characteristics of the guiding trucks and the leading drivers. This determines the use of draw-bars, Mallet hinges or ball joint connections between units. With the use of a hinge there are definite conditions which necessitate it to function either as a restrained or unrestrained member, that is, the connection can act as a hinge or as a draw-bar.

The statement is made in the paper that the booster equipped locomotive is desirable from a track stress standpoint.

It should not be overlooked that the locomotive as a whole may be somewhat lightened by the application of a booster to the trailer axle, but when treated as an isolated case, such a condition is decidedly detrimental from the track stress standpoint, due to the long wheel spacing and heavy loading causing high reverse bending in the rail. If a booster is desired then its application to the four-wheel trailing truck and tender should be given consideration.

The paper treated of resultant rail stresses. It is equally important to be able to make an analysis which will include the resolution of such stresses into their vertical and horizontal components and thereby determine the actual vertical and horizontal forces. A study of such forces along with the configuration of the locomotive for various wheel positions is a portion of the work which should be further prosecuted.

Our roadway tests for the determination of such stresses is by a magnetic extensometer, which is capable of measuring a change of 1/20,000 in. The accuracy of the stress reading will depend on the length of the extensometer. This instrument does not require special or artificial road-bed, but is directly applicable to the undisturbed road-bed. It is essential that this condition of undisturbed road-bed exist.

J. A. Pilcher (N. & W.): Mr. Ripley and the Santa Fe are to be congratulated upon the work done in following up that of the American Society of Civil Engineers and the American Railway Engineering Association, through their Joint Committee, headed by Prof. Arthur N. Talbot.

A great deal of time is needed to read over and digest the mass of information accumulated, and the data in Mr. Ripley's report. Because of the fact that there is so much data and there are so many variables, I may lay emphasis on different factors than those emphasized by Mr. Ripley. There is one point in which we will certainly agree; viz., that there are so many variables involved that an intelligent analysis is difficult and hence the field for the prac-

tical application of the stremmatograph to determine stresses under various conditions.

No only are there varying conditions in the locomotive, but there are varying conditions in the track. In so far as the locomotive is concerned, we have for variables the weight on the wheels; the spacing of the wheels; the lateral stiffness of leading and trailing trucks; the closeness with which tires are set to the gage of the track; the location and number of flanged wheels; the lateral movement of axles in the rigid wheel base; the length of rigid wheel base; the condition of counterbalance; the curvature of track; the overhang on the back end to which the load is coupled, and the amount of load pulled. All influence, in a measure, the stresses in the rails.

The major features over which the locomotive designer would has control are the counterbalance, wheel spacing; length of rigid wheel base; lateral stiffness of the leading and trailing trucks; overhang at the back end; the adjustment of tire flanges to the gage, and driving box lateral clearance.

1. *Counterbalance:* This is a feature that has always impressed the designer as one to which attention must be given. In the diagrams shown the track stresses with locomotives on tangents and at speed, the Pacific type locomotive at 60 m. p. h., are approximately 28,000 lb. per square inch on the third driver, the increase being from 18,000 to 28,000 lb. per square in. at from 5 to 60 m. p. h. The trailer, which has no counterbalance increases from approximately 20,500 to 23,500 lb.. This high stress on the third driver is when the counterbalance is down, but for the main wheel it is nearly as high when the counterbalance is up.

For the Mountain type on straight track, the stresses under the drivers run from about 16,000 lb. per. sq. in. at 5 m. p. h. to about 20,000 lb. at 60 m. p. h., the stresses under the trailer being higher at 5 m. p. h. than under the drivers, and about the same at 60 m. p. h. In this case also the stress under the main driver is highest when the counterbalance is up instead of down. This shows the diligence needed in taking care of the counterbalance of the main wheels including the cross balancing due to the long overhang of the weights on the main pin where the main rod has to be coupled outside of the side rods.

For the Mountain type on curves, the stress at 5 m. p. h. has gone up to about 46,500 lb. per sq. in. under the third driver, the pressure being on the outside of the inner rail at that point; under the main driver in the same direction, the stress is about 35,00 lb., also on the outside of the inner rail; under the leading truck, the stress is on the outside rail, and is about 21,000 lb., while under the trailing truck it is outside of the outside rail and about 22,000 lb. and also inside of the inside rail and about 26,000 lb. There are some modifications at 25 m. p. h., evidently brought about by the centrifugal force of the locomotive on the curve. The pressure against the inner rail is reduced under the drivers, and the forces against the outer rail under both leading and trailing trucks are materially increased, the leading truck pressure going up to about 26,000 lb. per sq. in. on the outside of the outer rail, and for the trailing wheel to about 42,000 lb on the outside of the outer rail, the load on the inside of the inner rail being materially reduced, undoubtedly due to the decreased weight on the inside wheels due to the centrifugal force.

Our first reaction to the above statement is that the curvature of the track and the design of the locomotive to adjust itself to the curvature are greater factors in track stresses than the counterbalance, although both must always of necessity be considered.

It is to be noted that with this engine stresses from curvature and counterbalance together have run up as high as 42,000 lb. per sq. in., whereas, with the same type of engine, with the counterbalance only considered, the stresses went up to 20,000 lb. at 60 m. p. h., but only about 17,000 lb. at 40 m. p. h., which is nearly comparable with the speed at which the stress went, on the 10 deg. curve, to 42,000 lb. This is an increase of 25,000 lb. due to curvature.

In the second progress report of the Committee on Stresses in Railroad Track, published in the 1920 transactions of the American Society of Civil Engineers, there are a series of diagrams of the average stresses in the rails throughout the revolution of drivers, showing the position of the counterbalance in parts of the revolution, and diagrams showing stresses for high and low position of the counterweight, including tables for the various wheels with the up and down position, and the mean values, with tables showing the ratio of maximum stress, mean stress, and additional stress to the stress at 5 m. p. h. for locomotives of the Santa Fe, Mikado and Pacific types; also diagrams of the locomotives, weight per wheel, and tables of counterbalance weights.

In these tables the stress at five m. p. h. is placed at unity. For the Santa Fe type the maximum speed is 50 m. p. h. The greatest variation is with the main wheel where the stress is 3.68 and 3.75, respectively, times as great at 50 m. p. h. as at 5 m. p. h., and is with the counterbalance up instead of down; 2.09 and 1.92, respectively, of those are attributed to speed and 1.59 and 1.83 respectively, to counterbalance. The next largest effect is that of the second driver and is 2.25 and 2.60, respectively, times as great at 50 m. p. h. as at 5; 1.48 and 1.83, respectively, of these are due to speed and .77 and .77 respectively, to counterbalance. Even on the trailers there is an influence due to the up and down position of the counterbalance.

With the Pacific type, the figures are very much less than for the heavier freight engine and the counterbalance effects are correspondingly smaller, showing the advantages of the better counterbalancing possible on this type.

For the Mikado the effects are greater than for the Pacific, but less than for the Santa Fe. The above variations are for engines on which the driving axle loads do not have a wide variation, the Mikado and Santa Fe types being nearly the same, while the Pacific type, which shows the lightest stresses is the heaviest on the axles.

While dynamic augment due to counterbalance, as compared to reactions due to curvature, may have the lesser influence in stresses, curve stresses are, in a measure, reaction stresses and do not necessarily deliver themselves to the ballast and to bridge structures; whereas, the counterbalance forces deliver themselves directly to the ballast and to bridge structures, and therefore, should be reduced to the minimum. The possibility of a reduction of dynamic augment is referred to in Mr. Ripley's paper as a possibility with three-cylinder locomotives. Experiments already made indicate that they can be counter-balanced for rotation only without excessive nosing. If such finally proves to be the case, this type may readily justify a slight additional maintenance cost, due to the center cylinder connection with the axle and the center valve operating mechanism.

2. *Wheel Spacing*: All observations indicate that close and uniform wheel spacing reduces track stresses. This, probably, is due largely to the lack of rigidity of the roadbed itself, and to the fact that the rail acts more in the nature of a continuance beam with the close spacing than with the long spacing, of a trailing truck located considerably back of the drivers. It may, therefore, be necessary to keep the weight down on a trailing truck so placed, and also reduce its effect in resisting

the turning of the engine on the curve, at the same time putting a heavier load on the leading truck where the weight will assist in turning the engine on the curve.

3. *Lateral Stiffness of Leading and Trailing Trucks and their Influence:*

This subject naturally goes with the preceding, and undoubtedly has a large influence in fixing the pivotal point of the turning of the engine on the curve. This turning and the reaction in connection with same bring about, so far as our observations of data would indicate, the greatest track stresses.

This has been called to our attention recently in connection with electric locomotives where two units of the same type are coupled together and where the leading truck becomes a trailing truck when the engines are operated in the opposite direction. The subject has been dealt with fully by Dr. Uebelacker, under the title "Investigation of Articulated Locomotives on Curves," in the supplement to the "Organ Fuer die Fortschritte des Eisenbahnwesens, N. F. Vol. XL 1903." A translation has been made by F. Uehler, of the Westinghouse Electric & Manufacturing Company. He has dwelt at length on the necessity of ample lateral stiffness to the leading truck and virtually a completely flexible trailing truck, even going to the extent of having a trailing truck that will help resist the lateral influence of the load being pulled at the rear of the engine, which tends to increase the reaction against the inner rail under curving. This study of electric locomotives by Mr. Uehler, and his simultaneous study with steam locomotives was largely for the purpose of reducing flange wear. Flange wear, of course, means pressure against the flange with corresponding reaction to the rail, so that the two subjects are closely allied. Uberlacker's calculations, of course, have to be based upon a number of assumptions as to the behavior of the trucks and wheels, and as to friction of the wheels on the rails and impingement of flanges against the rails, including a large number of other possible variables. His final analysis handles about thirteen major variables and the equations run to the third and fourth degrees, which make an exact solution impossible, and an approximate solution difficult. These results emphasize the inuence of the lateral stiffness of the trailer truck as well as the length of the overhang on the rear end of the engine back of the rigid wheel base, at the point the connection is made for pulling the train.

These figures indicate the desirability of a flexible trailer truck and the advantages of a radial drawbar attaching to the structure at or near the point of rotation, so as to reduce to a minimum the effect of lateral influence of the resistance of the following equipment to the turning of the engine on the curve.

Mr. Ripley deals with the desirability of a study as to how many wheels of a long coupled engine should be flanged, and when flanged, of the closeness with which the flanging fits the gage. This kind of data is useful to the designer only when he has a sufficient amount to determine exactly what is best in reducing track stresses. It will take a large amount of additional observation to indicate this for every different type of locomotive.

The author also speaks of the effect of lateral clearance between the wheels and the boxes. This clearance can be set when a locomotive first goes out, but is a variable hard to keep constant, so that a large study would have to be made to indicate the limits within which lateral must be kept to get the best results.

In general, these tests indicate that the track suffers most from the long, rigid wheel base locomotive, and it is in connection with this type that these lateral forces are greatest and where lateral clearances between hub liners and driving boxes are most needed.

4. *Articulated Locomotive:* This brings up the question as to whether the articulated locomotive having a shorter rigid wheel base will not materially relieve track stresses. Unfortunately we do not have any stremmatograph records to demonstrate what happens to the track under locomotives of this type, although, as stated, some work has been done with electric locomotives where units are working together in a similar manner, but not exactly like the articulated steam locomotive. It remains to be seen whether the complications incident to the articulated steam locomotive will be justified in the decrease they produce in track stresses. It is hoped, for the benefit of both those responsible for the track and for the engine design, that such experiments will be conducted.

5. *Centrifugal Forces on Curves:* In connection with the diagrams in the paper, it is to be noted that the reaction against the rails on curves, so far as the drivers are concerned, which reaction is against the inner rail, is reduced, but at the same time reaction against the outer rail by the leading and trailing trucks is increased, with the speed.

Most heavy engines with long, rapid wheel base, however, travel at slow speeds, so that this easing up on the rails, due to centrifugal force, on curves cannot be counted upon to any great extent.

6. *Breakage of Frames:* In studying the reaction of the different wheels of the engines against the rails, inner and outer, which reaction has to be taken up by some portion of the locomotive, viz., the frames, we find in the analysis of this report a factor which points to the reason for locomotive frame breakages. There must be large stresses where there are so many varying conditions, where the lateral forces react as between the center wheels of the engine and the leading and trailing wheels, bringing about enormous lateral bending moments in the frames against which the hubs of these wheels have to react. At present the direct stresses in locomotive frames, due to reaction of pistons, wheels, drawbars, etc., when taken on a unit stress basis, are small and cannot be considered as influencing frame breakages, to a large extent. The lateral pressure, however, of the wheels against the rails, throwing the frames in lateral bending under varying conditions, indicates to the locomotive designer the way in which frame breakages could be reduced, viz., making the two frames of a locomotive in practically one piece, or connecting them together in such a way that each side frame becomes a flange of a deep horizontal girder with a web connection at or near the top of the frames as it is practicable to make it, and at each pedestal so crossbraced that the whole becomes as one in its action to resist lateral bending. This we now understand is being tried out in the making of one-piece cast-steel locomotive frames, and we can but hope, in the light of this analysis, for an almost practical elimination of broken frames.

G. L. Fowler: I approached this matter of track stresses from an entirely different standpoint than Mr. Ripley and reached the definite conclusion that it is not altogether the locomotive but a combination of the locomotive and the track which produces the stresses.

My work has been entirely devoted to that of measuring the lateral stresses of the wheel against the rail. I found that the greatest stress is caused by the leading wheel at the higher speeds, followed not by the second wheel, but by the third wheel—the second driver. I found that the stress was almost exactly on the lines of a parabolic curve. The value of the parabolic curve, $Y^2=2PX$, 2P being the constant. Then there is a constant to be added to that equation, it becomes; $Y^2=2PX+$ this constant, and that constant also varies with the type of locomotive. No locomotive can be expected to develop stresses or impose loads that are exactly in

accordance with that equation, but that is near enough so you get two constants and very reliable results.

Then in the matter of stresses on straight track, the apparatus we used was about 240 ft. long, and we took the total thrust of the whole locomotive. We found that we could take a Mikado locomotive and run it over the track at 30, 40, or 50 m. p. h., and take a Pacific locomotive and run it over at 30, 40, 50, or 60 m. p. h. and that if we got a high accumulated load at any one point and a low accumulated load on another point, it would follow straight through the whole length of the apparatus so that the intensiveness varies but the point of high and low application did not vary at all.

The track was on a tangent fill about five feet high. The foundation is such that the track is flexible with a freight train running over it so you could see the track sway.

Then in regard to the distortion of the track we find that by putting a hump on one side of ½ in., there was practically no influence on the engine either in its effect on the track or on the engine itself. By raising it to ¾ in., it became perceptible, but if we put a ¾-in. hump on, and then went back on the other side and put in another one, then we began to get results that were very noticeable. As a general rule the lateral truss of a sleeping car was very much above that of the thrust of a Pacific locomotive, and a switching locomotive is the worst thing that can be run over a track, next to a consolidation running backwards. The six wheels of a sleeping car truck are practically in identically the same condition as the wheels of a switching locomotive, with no guiding truck. The pressure on a sleeping car would be 2½ times as high as it would be on a Pacific locomotive, at the same rate of speed.

On the straight track when we are running with old engines, the wheels would lash backwards and forwards and hit against the rail, but the locomotive drifted along on its straight course without any apparent effort. If you take an engine that just comes out of the shop, when everything is on tight, then look out for lateral blows.

Arthur Knapp (N. Y. C.) :— The problem of distribution of increased wheel loads and development of rail design and material available for rail purposes to carry these loads, deserves serious consideration if we are to maintain the required margin of safety and permit further progress in railroad transportation.

A wide margin between loads and carrying capacity must be provided to accommodate variation in loads as well as variation in quality of material, and each increase in load requires a corresponding increase in the carrying capacity of the rail and track. Knowledge of service requirements and great skill and ingenuity have been employed in prefecting the design of rail sections so as to afford the present efficiency due to design. The ores available for steel making and study of service records has resulted in a choice of basic open hearth steel within a specified range of chemical composition as the most suitable material available for rail purposes. This has been supplemented by higher standards of maintenance and rigid requirements as to tests and inspection for acceptance of finished material. The equipment engineer is exercising his best knowledge and skill in the development of locomotive design so as to secure the maximum efficiency in power with the minimum of stress.

Our attention has been directed to further improvements which may be employed with great advantage to the track and equipment. The improvements which appeal to me as the most important are those which promise a higher degree of uniformity. The Rail Committee of the American Railway Engineering Association, the members of that committee as individuals, and many other engineers interested in rail service, have devoted a vast amount of time, thought, and large expenditures to the development of uniform quality in rail steel. There is much yet to be accomplished in that direction. The equipment engineers realize the importance of uniform loading.

C. B. Bronson (N. Y. C.): The late Dr. P. H. Dudley was a pioneer in this field, and I wish to call attention briefly to some of the fundamental work he initiated. His study of general track structure, particularly rail, was commenced in 1878, using for the purpose a recording track indicator. The conclusion reached after accumulating records representing thousands of miles of track was that rail sections heavier and stiffer than the 65 or 72 lb. rails were essential to maintain track at the highest standard. He designed the pioneer five inch 80 lb. section in 1883, and it was installed in 1884. His attention was then directed to the study of the methods and mill practice in rolling rails from which he developed rail specifications that are the basis of most of those in use today. The six inch 100 lb. section was designed in 1892, to permit the use of heavier power and rolling stock, and to draw train loads twice and even three times those of previous years.

Exact knowledge of the relation of rolling wheel loads to the rails was meager in the eighties and early nineties, though there was much theoretical discussion with little test data to substantiate assumption. It was because of this situation that Dr. Dudley developed the stremmatograph in 1896, and obtained the first actual records of the strains in the base of the rail under wheel loads moving at high speeds.

The first tests were made in 1897 on 65 and 80-lb. rail with 4-4-0 passenger and 4-6-0 freight type locomotives, and with the long spaces between drivers the stresses on the lighter rail were over 35,000 lb. per sq. in. in some of the tests. As the Atlantic, Pacific, and Mikado locomotives were successively introduced other test data were collected on the 5⅜-inch 80-lb., 6-inch 100-lb., and 6-inch 105-lb. rails. The utility of girder stiffness in the rail section was readily apparent, for the wheel load effects were distributed over several ties even under the heaviest power on the higher sections of rail.

The laws governing the movement of the locomotive and the distribution of the loads to the rail and roadbed were sought and determined as the test data accumulated and enlarged. It was noticed that the induced stresses in the rail base very seldom checked for an individual wheel in two or more runs at the same speed, though the sum total of the strains of tension and compression for all wheels of the locomotive generally checked within one or two per cent. This indicated that the locomotive distributed its wheel loads as though from the longitudinal center of gravity, for both the static weight and dynamic effect of each wheel load varied a considerable extent due to a number of factors in track construction and locomotive design which are difficult to control entirely.

In plotting results, the summation of the stresses is used rather than those for the individual wheels, though the computations are carefully considered to determine maximum and minimum stresses for any particular wheel. Two series of tests on 80 and 100-lb. rails were made with a Mikado type locomotive having a main driver axle load of 68,000 lb. The large difference between total stresses for the light and heavy rail sections was quite noticeable, especially as the higher speeds were attained, where the effect of acceleration, unevenness of track, lack of girder strength and other inherent weaknesses of the lighter rail become accentuated.

Another series of tests of interest was made on 6-in.

105-lb. rails with Pacific type locomotives with and without booster on the trailer axle. The load on the main driver was 68,000 lb. while the trailer load without booster was 53,000 lb. and with booster 57,000 lb. The effect of the booster weight at high speeds was to increase the stress about 1500 lb. per sq. in. With the booster in operation at speeds of less than 15 m. p. h., a considerable increase in stresses at the rear end of the locomotive was noted, though the highest stress was quite moderate in all of the tests.

Tests under the Mikado type locomotives have shown the importance of placing sufficient weight on the forward truck to depress and take up any looseness in the track, or "iron it out" for the following heavier loads of the drivers. The stresses produced by the latter are surprisingly low, considering the axle loads, on account of the spacing between wheels being short and all acting in the same general depression of the rail. It is necessary, however, for the engine to be properly counterbalanced to attain these results; a condition which is found to be generally true for the drivers of 69-in. to 79-in. in diameter. The trailer load, though lighter, produces the highest relative stress, because of the longer span for its wheel spacing.

The constant increase in weight placed upon the trailer axle and rear end of the locomotive has raised the average of stresses for this wheel and has placed added burden on the rail to sustain. Mr. Ripley's suggestion for the installation of four-wheel trailer trucks on some of the heavier power units, based on experimental data collected by him, should receive careful consideration by the designers and builders of locomotives. This type of construction will materially lower the unit stresses in the rail, create greater uniformity, as well as make a smoother general track depression.

Direct bending stresses, as indicated above, are not excessive in the stiffer rails under the heaviest types of power, for they seldom exceed 25,000 lb. per sq. in. for the six in. 100 lb. or 105 lb. sections, with the average less than 20,000 lb. Recent information for the 130 lb. section shows that the stresses rarely exceed 18,000 lb. as a general proposition, based of course on tests on tangent track or light curves, and properly counterbalanced engines. With poorly counterbalanced drivers, almost anything may be expected, and it is therefore important that the operating speed restrictions should be more severe for locomotives in such condition to avoid injury and deterioration of the track structure.

An important field of investigation which has been somewhat neglected is the distribution and effect of freight car wheel loads on rail. It was shown from a number of stremmatograph tests made under freight trains that shocks or blows were delivered of such force as to throw the instrument out of line, blunt the needle bar point, and blur the record. Experience seems to indicate that as much if not more total damage is done to track by the wheels of heavily loaded cars as by the heaviest types of power. This is especially true when the freight car wheels are out of round, springs completely compressed and the loads swaying from side to side. One eastern road, in studying its rail failures, found nine times as many in their eastbound track, carrying the loads, as in the westbound track hauling the empties, though, of course, the same power operated in both directions.

Records are kept of the rail failures on the New York Central, classified as to type, manufacture, service, age, etc. The records of many roads indicate that about 80 per cent of the failures occur in the rail head, those in the base and web having diminished to a small factor. Some roads report an abnormal number of failures at the rail ends through the bolt holes, but those on the New York Central are few, which fact is attributed to the use of a three-tie supported joint and a long angle bar with six bolts.

The stresses in the rail base can be, and are being reduced, even with the installation of heavier power, but with the introduction of rails of increased height and stiffness, the intensity of pressure on the head metal is not being reduced, but augmented, due to the great pressure concentrated in the metal in the rail head tending to crush, split, or otherwise deform it. This is a serious matter and needs the utmost consideration.

The physical properties of basic open hearth rail steel as now manufactured cannot be greatly improved unless by heat treatment or use of alloying elements. Some experiments have been made along this line, and while the physical properties of the metal have been improved the cost is excessive, and other undesirable features are encountered.

The New York Central aims to reduce the average intensity of pressure by two features of design:

First—The rail head is made broad and thin, and has a flat top radius. This type of head permits the rolls forming the section to completely work the metal and obtain the maximum physical properties due to the composition without resorting to the use of an excessively high carbon steel.

Second—The wheel tread is designed to more nearly conform to the contour of the rail head, with the taper on the tread of 1 in 38 nearly to the outer face of the rim. The combined effort secures the maximum area of contact with consequent lowering of the average intensity of pressure.

Several series of experiments were made on the New York Central to obtain static areas of contact under locomotives and cars and on six-inch 100-lb. rail. The method followed was to move carefully each wheel upon a steel wedge, then lower it on a copper sheet of .0015 in. thickness resting on the rail head.

Tests were reported by the American Railway Engineering Association on rails in which holes were carefully drilled transversely through the head and at various depths. After preliminary experimental loads were passed over the rail in the laboratory, the rails were placed in service under heavy traffic, and within a short time the holes nearest the top were completely closed and later distortion progressed to a depth of more than 3/8-in., especially on the gage side. Micrographs of the structure of the steel showed severe grain distortion and the penetrating effect of wheel pressures.

Stress in rails on sharp curves is more or less of a special problem in view of the fact that a small portion of the track mileage in the United States is in curves exceeding five degrees. It has been demonstrated that high stresses in the rail base on curves can be lowered by adjustment of superelevation, change of track gage, close mounting of the wheels on some of the axles or other changes in design of equipment. Each sharp curve and the traffic over it presents a special problem and needs to be studied separately to produce the least wear, lowest stresses, and be placed in the most satisfactory condition for the operation of trains.

Curve wear of rails is overcome by a special steel containing about 12 per cent. manganese. The experience of some roads having combined steep grades with sharp curves does not bear this out, but on fairly level territory, using a section of ample girder stiffness to offset the low elastic limit of this type of steel, no other material seems to approximate the life and service of rolled manganese steel for this purpose. The failures are negligible, while crushing and distortion of the head metal is kept at a

minimum. The adhesion, however, is less than an ordinary open hearth steel so the drivers have a tendency to slip and burn the rail head, starting transverse hair cracks which develop slowly by detail through the section.

The desirability of close co-operation of track and motive power departments is apparent. The New York Central has followed a policy of co-operation in all matters of track, power and equipment for many years, and the design of each new class of locomotives is given consideration as to its effect on track, and changes are suggested and made wherever possible to improve or lower the resultant stresses. At the same time an effort has been made to design the rail sections and general track structure to keep pace with anticipated progress to meet the requirements of the operating department for speed, dependability and safety.

(Written discussions of Mr. Ripley's paper were also presented by Lawford H. Fry (Standard Steel Works Company) and Prof. R. A. Talbot. Mr. Fry's discussion contained diagrams received too late for reproduction. Prof. Talbot's discussion will be found elsewhere in this issue.)

Report of Committee on Locomotive and Car Lighting

Design of battery boxes, axle generator belt drive and photometry of locomotive headlights are three important subjects now in the hands of the committee. If a higher battery box is found practicable it will mean extended washing and flushing periods and reduced damage to trays and battery connectors. There is a real need for some kind of an axle generator pulley which will keep belts on body-hung equipment in alinement and thereby obtain belt mileage comparable with that obtained on truck-hung machines. Progress made indicates that this goal can be reached. A standard method of making photometric tests of locomotive headlights is needed so the performance of lamps and reflectors can be determined accurately. Standard lamps and reflectors and elimination of the focusing device are a possible outcome of proper photometering methods. Ultimately this should result in simplified headlight maintenance and better light for the enginemen.

W. E. Dunham
Chairman

Present day practices indicate that greater clearance above batteries than that provided in the standard practice for battery boxes and trays is desirable. The committee is investigating this subject and anticipates having recommendation ready for presentation at the next convention.

Locomotive Cab, Classification and Marker Lamps

The committee has requested several railroad members to make a test of the S-14 bulb lamp, in addition to those members who tried out some of these lamps as suggested in the report of last year.

For the information of the members the following outline (Fig 1) of the two lamps in question, the S-14 and the S-17, is shown, from which it will be seen that the local centers are not exactly the same distance above the plug and there may be some necessity for a change in the construction of the present cab or marker fittings.

Axle Generator Belt Drive

Last year's report made reference to the use of barrel type axle pulleys of two lengths, 33½ inches and 28½ inches. Of these pulleys the latter length is being used in preference, principally on account of clearance required for application and fastening.

About forty-five (45) of the universal axle pulleys are being placed in service and it is anticipated that the coming year will bring out some definite service information on this type.

Car Lamps

As noted in last year's report, member roads recommended adding to the list of recommended lamps the following sizes and types:

25 Watt, 30-34 Volt, P S-16 bulb, filled.

100 Watt, 30-34 Volt, PS-25 bulb, Gas filled.

On account of the quite extensive use of these lamps the committee recommends referring their adoption as recommended practice to letter ballot.

Photometry of Locomotive Headlights

The present recommended practice, adopted in 1915, is believed to be in need of revision and to be brought up to present-day practice. The committee, therefore, recommends that this subject be referred jointly with the Association of Railway Electrical Engineers, to the Bureau of Standards for their recommendation.

Dimensions for Headlight Reflectors

The dimensioning of glass reflectors has received some consideration with a view to the development of a reflector that can be made to interchange with any make for any equivalent size of headlight case. Your committee feels that the dimensions of a glass reflector should be taken from the same points of origin as those for a metal reflector wherein the reflector surface is the front of the reflector, whereas the reflecting surface of the glass type is the back surface, which involves thickness of glass, refraction, etc. Figures 2 and 3 illustrate the development of a glass reflector on this basis.

The construction of the path of a light ray through a glass parabolic reflector will be seen in Fig. 2. The ray from the focus, incident upon the front surface of the reflector at p is refracted and its direction is changed in such manner that $\frac{ab}{n} = a'b'$ where n is the index of refraction for the glass used, a and a' lie on an arc struck with p as a center, and b and b' lie on the normal to the front surface at p.

It will be noted that the rays op and ip' produced intersect at e. The focus of the point e has been termed the "equivalent parabola." Its properties are such that a metallic reflecting surface through all points e, will exactly duplicate optically the performance of the glass reflector from which e was determined. In general e lies on the back surface only at the apex of the reflector, and gradually approaches the front surface, but is coincident with the front surface only at infinity. It is this equivalent curve to which the optical properties of the reflector should be referred. The effective reflector diameter is thus seen to be the inside diameter since the diameter to e and p' are seen to be identical. The focal length is measured to the back surface of the reflector, however, since e coincides with the back surface of the apex. This method for dimensioning reflectors coincides exactly with established custom in the case of the metal reflectors, where rated diameters, focal length and depth were located from the effective reflecting surface to which e corresponds. The effective reflector depth may vary somewhat in various designs due to difference in glass thick-

ness and contour of the glass surface, but these differences are relatively small.

In Fig. 3 it will be seen that in consideration of the foregoing the important optical dimensions are "A," "B" and "C." "A" is the effective reflector diameter. A tolerance of plus or minus 1/16" is considered as suitable in consideration of the best present glass working practice.

"B" is the overall depth of reflector and may be allowed to vary not to exceed plus or minus 1/4" for the various designs of reflectors conforming to the dimensioning used in Fig. 3.

"C" is the focal length. To avoid the necessity of measuring from a point in space "C" may readily be determined by measuring "D," the difference betwen "B" and "C."

"E" is the diameter of the opening at the apex of the reflector to permit the proper adjustment of the lamp. The diameter of

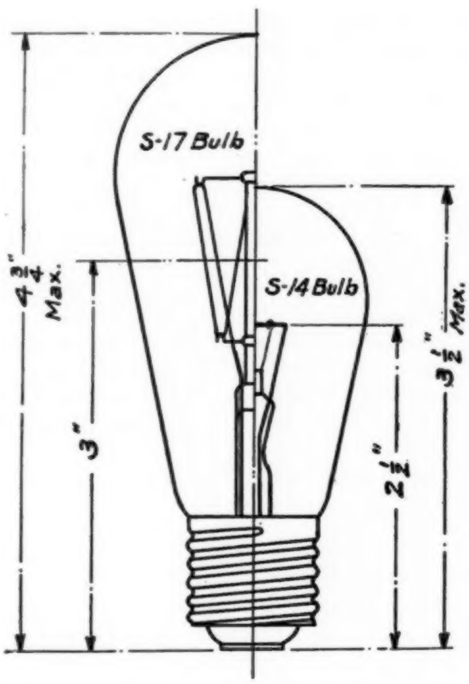


Fig. 1—Lamp in S-17 Bulb Now Generally Used for Classification and Marker Lights Compared with Lamp in S-14 Bulb Proposed for Same Service

this opening will vary somewhat depending upon the character of focusing device used, but will, in general, be about 2 3/4".

"F" is the outside or maximum diameter of the reflector. It is essential that this diameter be given to insure that the reflector shall fit the shield or retainer used. The outside edge of the reflector should be beveled slightly to prevent chipping of the glass and to provide a true edge for attachment. The thickness of the lip formed by the bevel should be a minimum of 1/8".

The focus of the point e, Fig. 2, is the basis for the design of a glass reflector, and it is felt should properly be the basis for all dimensions. If this is done, the dimensions will be taken from the same points of origin as for a metal reflector, and on this basis the diameter of the reflector would be the inside diameter at the mouth of the reflector, and the focal center would be measured from the outside or back surface, instead of from the inside, or front surface, of the reflector.

The committee recommends referring the dimensions of glass headlight reflectors to letter ballot for adoption as recommended practice.

Fusing Pilot Lamps to Prevent Fire

A member has recommended that pilot lamp circuits in passenger equipment cars be fused. The committee does not believe that this is necessary. The report is signed by W. E. Dunham (Chairman), superintendent car department, Chicago & North-Western Railway; E. Wanamaker, electrical engineer, Chicago, Rock Island & Pacific Railway; A. E. Voigt, car lighting engineer, Atchison, Topeka & Santa Fe Railway; J. L. Minick, assistant engineer, Pennsylvania Railroad System; W. H. Flynn, superintendent motive power, Michigan Central Railroad; E. W. Jansen, electrical engineer, Illinois Central Railroad; E. Lunn, electrical engineer, The Pullman Company.

Discussion

W. E. Dunham (C. & N. W.): The paragraph on photometry of locomotive headlights is changed by the Committee to read as follows:—

"The present recommended practice adopted in 1915 is believed to be in need of revision and to be brought up to present-day practice. This committee would, therefore, recommend that this subject be one for investigation and report at the next convention, working jointly with the association of Railway Electrical Engineers."

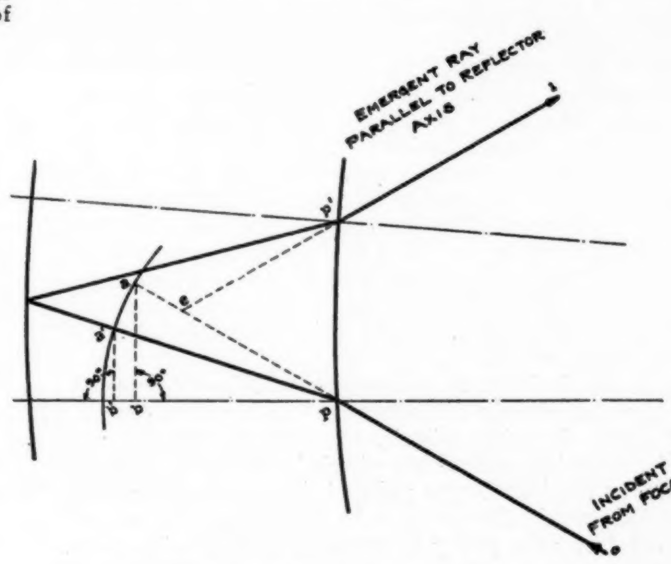


Fig. 2—Construction of the Path of a Light Ray Through a Glass Parabolic Reflector

A. McGary (N. Y. C.): The lighting electrically of railroad equipment presents a great many problems requiring lengthy study and investigation. We are constantly striving to improve lighting service and to bring about better operating conditions, with a view to obtaining the utmost efficiency.

Reference is made in the committee's report to providing more overhead clearance in battery boxes to

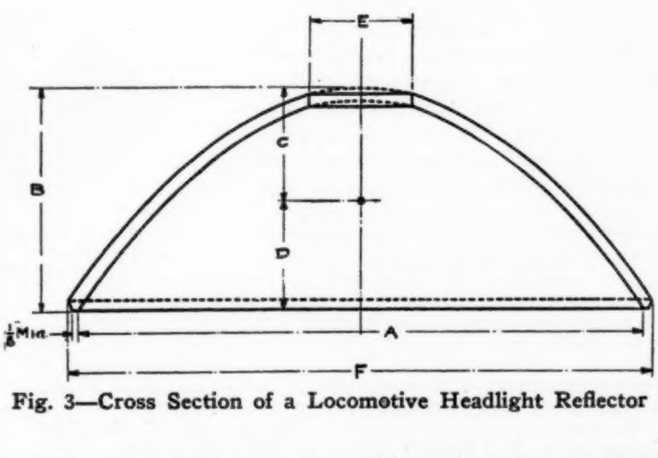


Fig. 3—Cross Section of a Locomotive Headlight Reflector

permit more ready inspection of batteries and to reduce to a minimum the labor necessary in handling them in connection with their maintenance. This is highly desirable and is a feature we have been very favorable to.

We have also advocated the adoption of a battery box whereby batteries may be assembled in single row. This box provides for increased overhead clearance and has a two-section metal door, the lower section being sup-

ported and held in place by recess clips and secured to the main box by use of bolts fitted with gravity nuts. The upper section of the door is hinged to the lower section and is held in closed position by means of staples with pins. When the hinged upper section is open it swings against the lower section, giving excellent clearance and accessibility to the battery for inspection and flushing. By this single row assembly, the necessity of pulling batteries out for inspection, gravity reading and flushing is eliminated, as all cells are front cells and can be readily cared for.

This type of battery box and battery assembly has many commendable features, of which the following are a few: Possibility of opening the door and giving battery attention where high platforms, retaining walls, etc., are encountered; elimination of damage and possible loss of door should the hinged section swing open in the event of inspector failing to properly secure it; less wire in the battery circuit, due to the use of short battery connectors instead of long connectors necessary in standard assembly where slack must be provided to pull out the crates for inspection of back cells; complete elimination of wear on battery box floors and crates due to present method of handling, thereby greatly prolonging the life of both battery crates and boxes.

We do not feel that the advantages obtained by use of wide face axle pulleys will offset the disadvantage experienced when changing wheels, where such changes are made by dropping and raising wheels by means of a center support, as the barrel type pulley being set in the center of the axle would first have to be removed. The use of the wide face axle pulley is confined to cars with clasp brake trucks, as these pulleys cannot be used with a single beam type truck.

With reference to the adoption of the PS 18 size lamp. The committee, in their 1923 report, explained that, "In anticipation of a rather radical change in the dimensions and type of bulb used in train lighting, it is not advisable to do so at this time." This matter has been taken up with the various lamp manufacturers and none of them seem to have any knowledge of the radical changes referred to by the comittee. It is our opinion that the PS 18 size bulb should be included in the list of recommended standards as the consumption of this size lamp by the New York Central and its lines would certainly justify its adoption.

J. L. Minick (Pennsylvania): I want to call your attention to the demands of the glass reflectors for headlights. There are several manufacturers of glass reflectors, and so far as I know, they are each using a method and dimension peculiar to themselves. The report of the committee holds forth what we think to be the proper method and is not a compromise as between the several manufacturers. If the report of the committee is submitted to letter ballot and approved we would like very much to have the member roads follow out this method of dimensioning very religiously in order that we can get a real standardization of glass reflectors.

The Chairman: Is there any further discussion? If not, what action do you wish to take on the paper?

Mr. Minick: Mr. Chairman, I move that the committee report be accepted and the various items submitted to letter ballot.

The motion was seconded and carried.

Committee on Electric Rolling Stock

The part of the report included under the subtitle "Proposed Outline for Future Work" indicates that the work of the committee is in capable hands. It expresses a good understanding of the advantages and disadvantages of electrification and it provides a clear picture of the railroad man's position and attitude regarding the use of electric motive power. The report of the subcommittee on recommended instructions for maintenance of electrical equipment of rolling stock indicates that it will not be difficult for the several users of electric motive power to draw up a general form of instructions for maintenance and inspection of electric rolling stock that would be applicable in all cases and of real value to those interested in electrification. The report of the sub-committee on operating problems includes clear and usable information on how electric locomotives are used for handling long trains on heavy grades.

L. K. Sillcox
Chairman

The committee, assuming the study of electric rolling stock, has taken a broad view of the scope of the subject and offers a suggestion for a comprehensive study of the application of electric motive power to existing main line steam railways or to extensions thereto.

In addition the committee presents reports on:

1. "Recommended Instructions for Maintenance of Electrical Equipment of Rolling Stock." This is a continuation of last year's report and represents an earnest endeavor to broaden the application and to overcome the objections raised at last year's convention. See Exhibit "A."
2. Operating Problems Encountered in the Handling of Long Freight Trains Under Electric Operation on Heavy Grades. See Exhibit "B."

A sub-committee dealing with the relative economy involved in the operation of passenger service when employing electric locomotives as compared to the multiple unit system has gathered considerable information regarding cost of maintenance and operation of multiple unit equipment and comparative cost of maintainance and operation of standard equipment when hauled by electric locomotives. However, complete data could not be assembled in time for presentation in the committee's report this year and the sub-committee will continue its work with a view of having a complete report available for next year.

Proposed Outline for Future Work

The committee feels that there is an apparent lack of a proper basis and a need for the establishment of a definite understanding on the part of steam railroad men as to the principles and factors involved in the adoption and operation of electric traction as applied to steam railroads. Generally speaking, railroad operating men, as a class seem to be insufficiently informed on the subject. This condition may be due to indifference or prejudice, or from a certain timidity caused by a disconcerting cloak of mystery that seems to

surround the study of electricity. There is a great need for an instrument that will change this viewpoint and bring about a more intimate knowledge and understanding of this important subject.

Electricity as an element of motive power has passed the experimental stage and has now reached the point where it must be considered as an important factor in the future growth and development of the railroads. How rapid the institution of heavy electric traction will be, cannot be predicted with a certainty for there are many conflicting influences involved in the evolution. However, the subject cannot be discounted nor laid aside and we as railroad men, owe it to our profession and to our constituents to acquire certain knowledge and useful information to enable us to dovetail into the future trend of growth and expansion.

It is not the intention of the committee to enthusiastically urge hasty and rapid evolution from steam to electricity nor on the other hand, to unduly retard such development, but rather by impartial and judicious statements of facts and principles to fore-arm and prepare the profession for unbiased study and judgment of future problems.

Aside from the practical phase of the subject there is that of public opinion. The public recognize in electricity, a factor in energy which in the past quarter century, has produced a remarkable evolution is the industrial and social life of the world. This form of energy, because of its convenience, its simplicity of transmission and application, and because of economies produced, has supplanted, to a large extent, other forms of power. The public has observed this transition and wonders why the adoption of electricity by the railroads is not more rapid, particularly since many public writers are advocating it and predict remarkable economics from its use. We, as railroad men, therefore, must acquire the facts and be prepared to combat this urge if it be groundless or to explain our hesitancy if the facts are correct.

That there are just grounds for hesitancy in substituting electric traction for steam on existing lines, even in the face of certain economies, cannot be denied by men well versed in such work. In the first place, electrification is very expensive. It involves a tremendous increase in the investment per mile, with the consequent difficulties, not only, of meeting the additional interest and other fixed charges, but of financing the capital necessary. The art of estimating, in advance, the cost of new construction, no matter if practiced by the most competent engineers, has not reached perfection, therefore where such large expenditures as those necessitated by electrification are contemplated, there is always the possibility that unforseen contingent expenses may cause the estimated figure to be considerably exceeded. The change to electric power will disturb to a certain extent, the interdepartmental relationship of the organization and will redistribute the proportionate burden of expense and responsibility such that any department head may be faced with the necessity of assuming an additional burden without compensating advantage. Changes in operating methods are often difficult and electrification immediately requires changes. In addition to educating enginemen to their new duties, a number of new men and crafts must be taken into the ranks. Transmission lines may overlap onto adjoining divisions confusing the duties of division superintendents. Signal systems have to be revamped. These and other features tend to disturb the existing order of things, and are conducive to caution and reserve.

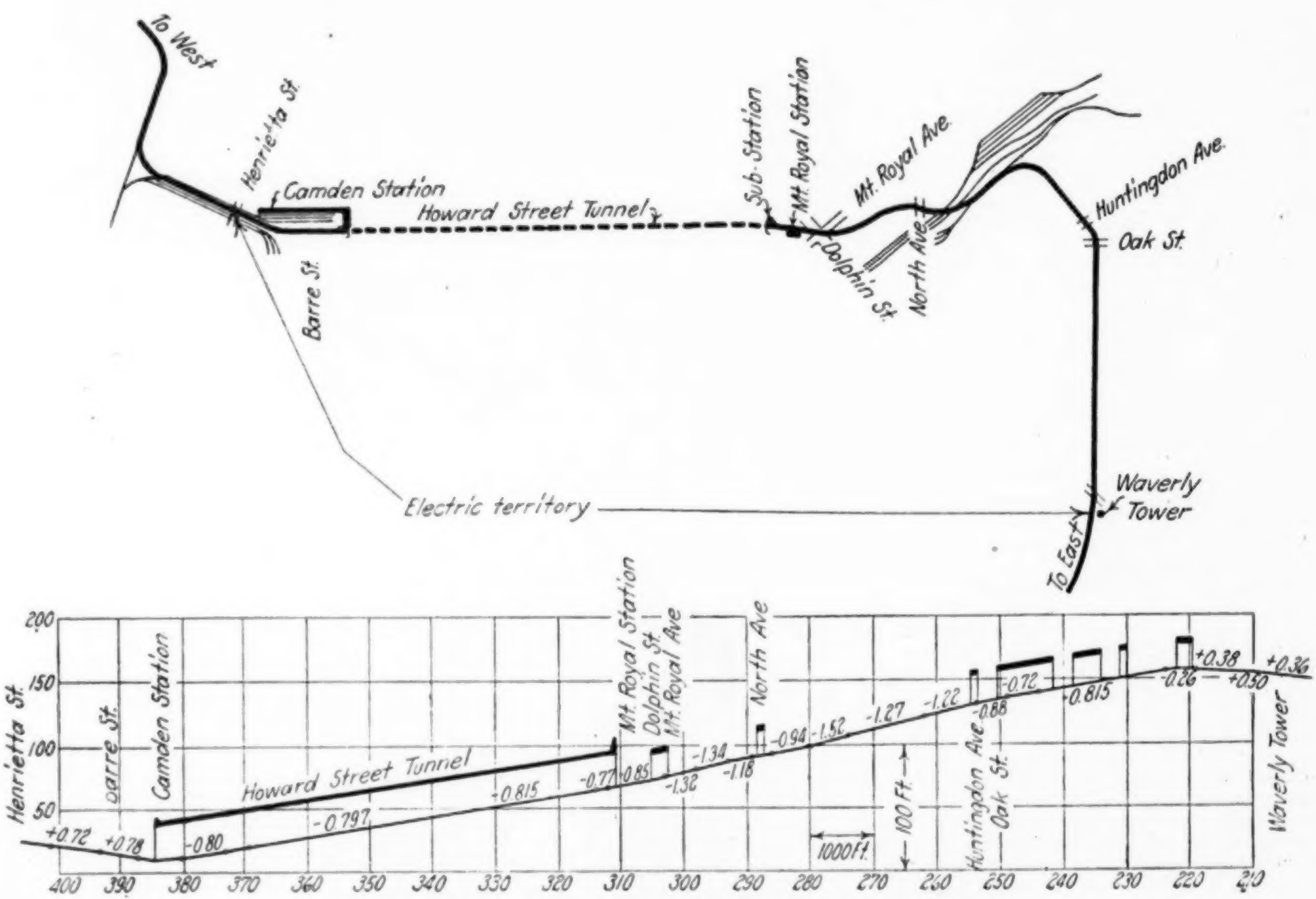
There are a great many basic questions to be considered and answered before it can be determined whether or not electrification is the solution to a certain difficulty. Generally speaking, it may be said that electrificatiou is prompted as a means of overcoming present or prospective obstacles and that economies in operation which obtain are of secondary consideration. Such physical difficulties may be classed under the following heads:

1. Terminal passenger traffic where it becomes imperative to move a peak traffic load in volume and speed beyond the limitations of steam operation.

2. To overcome a situation where smoke and gases from steam locomotives become a menace to life and health of employes and passengers or has brought condemnation from a city or community.

3. To overcome limitations of road such as grades or track capacity.

Viewing the subject broadly, it would seem that electrification of existing steam lines was not justified until after earnest effort had been made to overcome the situation at hand by applying all the refinements available in steam transportation. Of course, the cost of making such refinements and the improvements to be obtained should be carefully considered and compared with the cost and advantages that would arise from electrification. Competition may prove to be a deciding factor or public sentiment may force an issue otherwise unnecessary. Impairment to health from a smoke nuisance while in a



Map and Profile of Belt Line, Baltimore & Ohio Electrification

way inconsequential to railway operation appears large in the eyes of the public and the demand for electrification, therefore, to them does not appear unreasonable.

Wholesale electrification is not desirable and it is fortunate to the railroads and to the profession that the development has been slow. Each new undertaking has usually overshadowed previous installations and in some cases has practically placed them in the discard. It is not yet propitious to suggest standardization. It would certainly be unreasonable to urge the discarding of direct current for alternating or vice versa when a standard voltage for either has not yet been selected. The cost is too great to countenance a complete revolution; not only is it necessary to carry the burden of the cost of new equipment but electrification must justify the discarding of existing equipment and bear the burden of cost of retirement. Normal development is the safer procedure and will allow for gradual improvement to a point of perfection that could not be attained if an attempt were made to force a complete change within a limited period of years.

It is further necessary to develop the personal element, for even though it be true that steam enginemen can quickly learn to operate an electric locomotive and many other occupations also change as easily, yet, it must be remembered that certain additional occupations will be introduced and, above all, that supervisors and executives must be trained and educated to the new order of things, if the full benefits from electrification are to be realized. Co-ordination and co-operation are two essentials for successful electrical operation. A steam engine is a complete unit in itself and the work that it can produce is largely dependent upon the two men in the cab while, on the other hand, the electric locomotive is only one element of a big machine and is to a large extent controlled from Division headquarters. Economical operation with electric power depends greatly upon the load factor and this element of operation is beyond the control of the motormen.

The inception of the electric locomotive, as applied to heavy traction, has proven a big factor in the development of the steam locomotive. Progress in refinements has been quite remarkable of recent years with the result that we have steam locomotives today whose overall efficiency compares quite favorably with the best in stationary power plants, while the service produced also has improved When comparing steam locomotives with electric locomotives, consideration is seldom given to the fact that the electric locomotive is usually designed with a much greater reserve of power than is the steam engine.

Electric traction lends itself more to dense and rapid transit. Contrary to operation under steam power, electric power is more flexible under such conditions and does not require the reserve in locomotives. A more uniform load factor obtains and the whole system operates to best advantage. So long as such a condition exists, it is favorable to electrification, but as traffic drops off and the load factor becomes low, then the system must operate at a disadvantage and assumes a situation which must support a large percentage of idle capital with no chance of transferring the reserve to other points to relieve periods of heavy traffic. This condition exists principally on account of the heavy investment in fixed property such as power plants, sub-stations and power distribution lines.

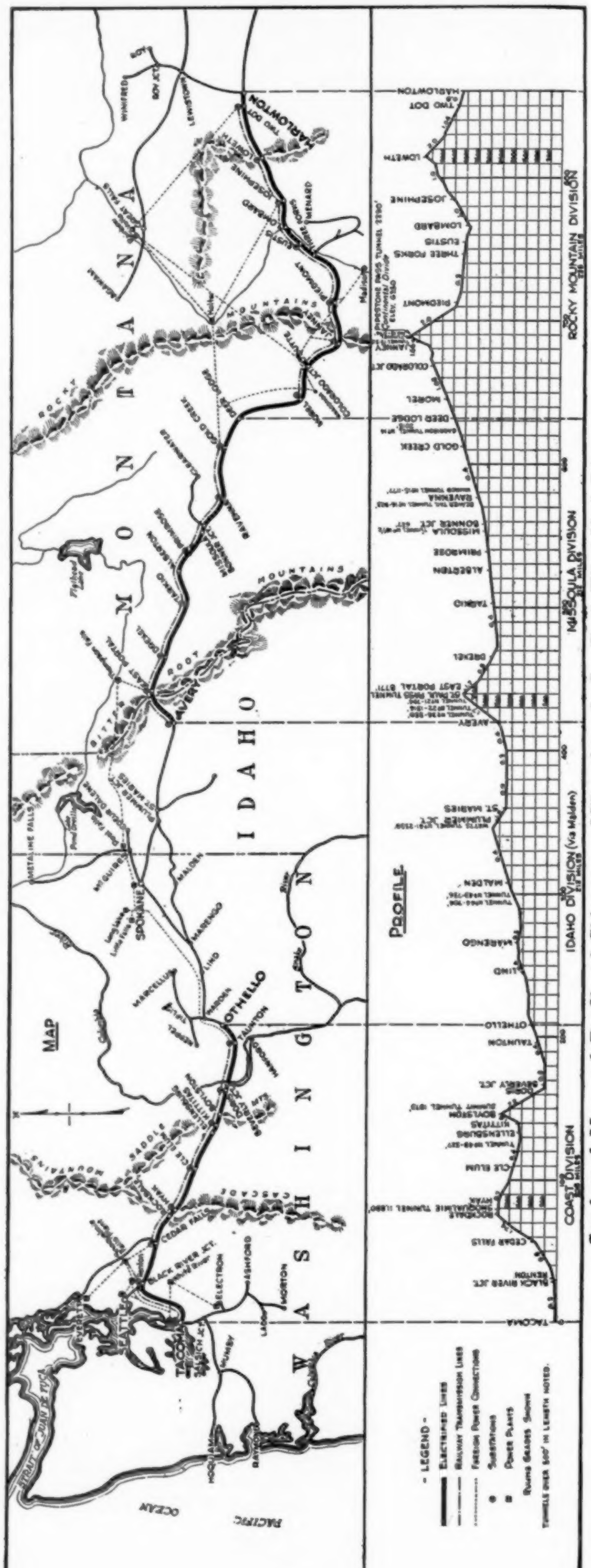
The propriety of these disparaging statements will be realized when the subject is impartially reviewed for the advantages are much more clearly defined than are the disadvantages. A few words of caution are quite necessary, for the human tendency is always to look with favor upon the newer order of things.

The preceeding discussion is intended as an opening paragraph to an extensive study of the elements and facts surrounding the evolution from steam to electricity in transportation. There is little doubt that this change will take place with increasing rapidity as time goes on. The advancing cost of fuel and the necessity of conserving natural resources are factors which will accelerate the movement. Until such times as conditions force the issue, isolated installations will continue to be made to overcome serious difficulties not readily overcome by steam transportation..

The logical beginning for a study of this nature is a research into the economics of the subject. Therefore, it would seem that the first problem to be solved is: When can an existing railroad afford to electrify on a purely economical basis. It is intended that this subject should be considered entirely in the abstract without any thought or bearing to the numerous outside compulsionary factors that usually enter into a project of this kind.

It is realized that there are a large number of subjects to be considered in connection with the study of electrification for heavy traction, but it is the thought that the subject of economics is basic to all else and must necessarily be answered first.

In line with the above, a joint committee on electric traction has been appointed, consisting of representatives of the Construction and Maintainance Section, Electrical Section, Signal Section, Telegraph and Telephone Section, Mechanical Division and Operatng Division, and the Committee on Electric Rolling Stock will be glad to receive suggestions from time to time as to subjects which it is deemed advisable they should consider and render any helpful assistance possible.



Condensed Map and Profile of Chicago Milwaukee & St. Paul Electrified Lines

Exhibit "A"—Report of Sub-Committee on Recommended Instructions for Maintenance of Electrical Equipment of Rolling Stock

At a meeting of the Committee on Electric Rolling stock held in Chicago on December 12, 1923, it was decided to review the study on recommended instructions for maintainance in view of the objections expressed at the 1923 annual meeting. This sub-committee was to endeavor to definitely state the experiences of the various railroads whereon electric traction was in operation to determine the mileage made between inspections and the reasons for same as well as the experiences leading up to the adoption of present practices. Also similar data was to be collected in connection with the periods of overhauling and detailed maintainance employed by different administrations, the reasons for same, and expressions as to the basis of present instructions in the light of past experience. It was felt that with this information exhibited, it being, in terms of actual practice, would permit a full consideration by all railroads, based on the evidence submitted.

A questionnaire embodying the points under contention was submitted to the following railroads:

Great Northern; Boston & Maine; Michigan Central; Canadian National; Southern Pacific; Butte, Anaconda & Pacific; Chicago, Milwaukee & St. Paul; New York Central; New York, New Haven & Hartford; Baltimore & Ohio; Norfolk & Western; Pennsylvania.

Replies were received from all excepting the Great Northern and the Butte, Anaconda and Pacific. The questionnaire with a resume of the answers received is tabulated below.

Resume of Answers to Questionnaire on Electric Rolling Stock

Question No. 1. Do you think it possible or practical to make a set of instructions applicable to all classes of electric rolling stock?

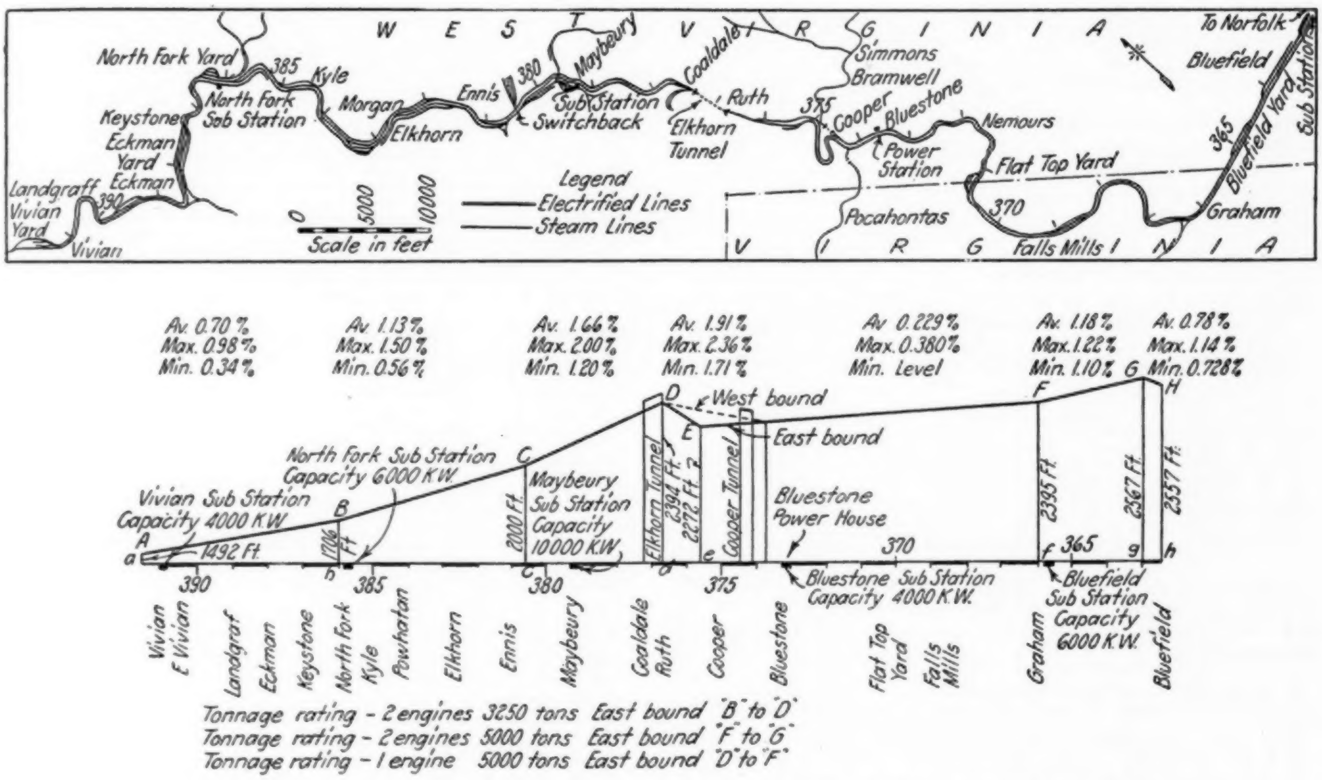
Canadian National—Possible but not practical.
Norfolk & Western—Not practical.
Michigan Central—Not practical.
Boston & Maine—Not practical.
Baltimore & Ohio—Not possible or practical.
New Haven—Yes, but general.
New York Central—Possible but not practical.
Pennsylvania—Yes.
Southern Pacific—No.
C. M. & St. P.—No.

Question No. 2. If not, do you suggest separate instructions for each class or would you recommend compiling a form instruction which could be used as a guide—specific mileages, voltages, and other features to be filled in to suit conditions?

C. N. Form instructions.
N. & W.—Form instructions.
Mich. Central—Instructions for each class.
B. & M.—Separate instructions with form as guide.
B. & O.—Separate instructions.
New Haven—Form instructions.
N. Y. C.—Separate instructions.
Penn.—As per last year's report.
S. P.—Form instructions with suggested practices.
C. M. & St. P.—Form instructions.

Question No. 3. Do you believe that mileage is the proper basis on which to establish periods of inspections and repairs?

C. N.—No. Based on days or number of trips for road power and hours for switching power. General overhauling on reports from regular inspections.
N. & W.—Yes.
Mich. Cent.—Yes.
B. & M.—Power input.
B. & O.—Yes, but suggest also K. W. hour basis.
N. H.—Yes.
N. Y. C.—Yes.
Penn.—Yes.
S. P.—Yes.
C. M. & St. P.—Mileage is the most convenient method. While kw. hour basis may be more accurate, yet this refinement not practical and not necessary.



Condensed Map and Profile of Norfolk & Western Electrified Section, Bluefield to Vivian

Question No. 3-A. What is your practice in this respect?

C. N.—72-hour period.
N. & W.—Regular inspection, 3,000 miles. No defined heavy inspection or classified repair periods.
Mich. Cent.—Regular inspection 100 miles. Heavy inspection, 600 miles. Classified repairs when necessity indicated by inspection.
B. & M.—Regular inspection 2,000 miles. Heavy inspection 25,000 miles, classified repairs 150,000 miles. Proposed to change to power input basis.
B. & O.—Not given.
N. H.—Running inspection each trip. Regular inspection 2,500 miles for locomotives and 2,000 miles for multiple unit cars.
N. Y. C.—Regular inspection daily. Heavy inspection, locomotives 3,000 miles, multiple unit cars 2,500 miles.
Penn.—On mileage basis. Mileages not given.
S. P.—Multiple unit equipment, regular inspection 1,500 miles. Heavy inspection 60,000 miles. Classified repairs 125,000 miles.
C. M. & St. P.—Regular inspection at completion of trip. Heavy inspection 5,000 miles for freight and switch locomotives. 7,000 miles for passenger locomotives. Classified repairs 120,000 miles for freight and switch locomotives, 140,000 miles for passenger locomotives.

Question No. 4. If so, what mileages would you suggest for the various periodical inspections, as indicated in the 1923 report; that is, for regular inspection, heavy inspection, and classified repairs?

C. N.—No recommendation given.
N. & W.—No recommendation given.
Mich. Cent.—Regular inspection 100 miles or at end of trip or day's work. Heavy inspection 600 miles. Classified repairs when indicated by inspection.
B. & M.—Regular inspection 2,000 miles. Heavy, 25,000 miles. Classified repairs 150,000 miles.
B. & O.—No recommendation given.
N. H.—Regular inspection for locomotives 2,500 miles. For multiple unit cars 2,000 miles. No other recommendations given.
N. Y. C.—Regular inspection road locomotives 3,000 miles. Switchers and multiple unit cars, 2,5000 miles. No other recommendations given.
Penn.—Regular inspection, locomotives 2,500 miles. Multiple unit cars, 1,500 miles. Heavy inspection locomotives 25,000 miles. Multiple unit cars 15,000 miles. Classified repairs, locomotives 150,000 miles, multiple unit cars 100,000 miles.
S. P.—Regular inspection 1,500 miles. Heavy inspection, 60,000 miles. Classified repairs 125,000 miles, but to be modified according to conditions.
C. M. & St. P.—Regular inspection at end of run or day's service. Regular inspection freight and switching locomotives, 5,000 miles. Passenger locomotives 7,000 miles. Classified repairs, freight and switch locomotives, 120,000 miles. Passenger locomotives 140,000 miles. No recommendation for multiple unit equipment.

Question No. 5. State briefly why such mileages are selected.

C. N.—No comments.
N. & W.—From experience.
Mich. Cent.—From experience.
B. & M.—Regular inspection, determined from main motor brush wear. Heavy inspection, accumulation of dust in main motors and wear in flexible drive. Classified repairs, necessity for general overhauling.
B. & O.—No comments.
N. H.—From experience.
N. Y. C.—From experience.
Penn.—From general data collected.
S. P.—From experience.
C. M. & St. P.—From experience.

Question No. 6. Do you consider a regular daily inspection necessary?

C. N.—Yes.
N. & W.—Yes.
Mich. Cent.—Yes.
B. & M.—Yes.
B. & O.—No.
N. H.—No, except engineers' report.
N. Y. C.—Yes.
Penn.—No.
S. P.—No.
C. M. & St. P.—No, but recommend inspection at completion of trip.

Question No. 6-A. What is your practice in this respect?

C. N.—Daily inspection.
N. & W.—Daily inspection.
Mich. Cent.—Daily inspection.
B. & M.—Daily inspection.
B. & O.—Do not inspect daily.
N. H.—Use engineer's report.
N. Y. C.—Daily inspection.
Penn.—Do not make daily inspection of electric equipment.
S. P.—Do not make daily inspection of electric equipment.
C. M & St. P.—Inspection at completion of trip.

Question No. 7. Do you recommend definite voltages for testing insulation for various pieces of equipment or would you suggest that such test voltages be indicated in percentages of the operating voltages?

C. N.—Percentage of operating voltage.
N. & W.—Percentage of operating voltage or voltage to ground as case may be.
Mich. Cent.—Percentage of operating voltage.
B. & M.—Percentage of operating voltage.
B. & O.—Percentage of operating voltage.
N. H.—Twice maximum operating voltage.
N. Y. C.—Twice normal plus 1,000.
Penn.—Definite voltages.
S. P.—Percentage of operating voltage to be modified with age of equipment.
C. M. & St. P.—Percentage of operating voltage to be modified with age of equipment.

Question No. 8. Please describe your method of making insulation tests and state at what frequencies they are made.

C. N.—Usually by magneto, 35.000 or 50,000 ohms. Meger for definite insulation resistance.
N. & W.—Use 5 kva. adjustable voltage testing transformer apparatus on entire locomotive testing yearly. Individual pieces when repair is made.
Mich. Cent.—Insulation tests made at each heavy inspection with voltmeter or meger.
B. & M.—Motor winding insulation tested with testing transformer only, and at general overhauling. Meger used occasionally on trolley insulators.
B. & O.—600 v. d. c. curicuits tested with 1000 v. a. c. 60 cycle.
N. H.—Use testing transformer 500 to 1500 v. a. c. for insulation tests at regular inspection periods, in nearly all cases. Pantograph supporting insulators tested with meger. Also test individual apparatus when repaired.
N. Y. C.—Insulation tests with meger at every second inspection.
Penn.—Use testing transformer and meger.
S. P.—High potential tests at periods of classified repairs.
C. M. & St. P.—High potential tests at periods of classified repairs.

Question No 9. Do you consider it necessary to remove motor generator sets at time of heavy inspections or to check output?

C. N.—No, unless necessitated by inspection.
N. & W.—No, unless necessitated by inspection.
Mich. Cent.—No, unless necessitated by inspection.
B. & M.—Yes.
B. & O.—No recommendation.
N. H.—Not necessary to remove unless necessity indicated by inspection, but recommend to check output.
N. Y. C.—No recommendation.
Penn.—No, unless necessitated by inspection.
S. P.—Yes.
C. M. & St. P.—No, unless necessitated by inspection.

Question No. 10. Do you consider it good practice when equipment is in for classified repairs to remove the field coils from traction motors, compressor motors, and motor generator sets?

C. N.—No.
N. & W.—No, unless necessitated by inspection.
Mich. Cent.—No, unless necessitated by inspection.
B. & M.—Not for main traction motors, but consider it good practice for small motors.
B. & O.—No, unless necessitated by inspection.
N. H.—No, unless necessitated by inspection.
N. Y. C.—No.
Penn.—No, unless necessitated by inspection.
S. P.—No, unless necessitated by inspection.
C. M. & St. P.—No, unless necessitated by inspection.

Question No. 10-A. What is your practice in this respect?

C. N.—Do not remove field coils unless necessary.
N. & W.—Do not remove field coils unless necessary.
Mich. Cent.—Do not remove field coils unless necessary.
B. & M.—Do not remove field coils unless necessary.
B. & O.—Do not remove field coils unless necessary.
N. H.—Do not remove field coils unless necessary.
N. Y. C.—Do not remove field coils unless necessary.
Penn.—Do not remove field coils unless necessary.
S. P.—Do not remove field coils unless necessary.
C. M. & St. P.—Do not remove field coils unless necessary.

Question No. 11. Do you consider it good practice when equipment is in for classified repairs to turn and undercut commutators?

C. N.—No, unless necessitated by inspection.
N. & W.—No, unless necessitated by inspection.
Mich. Cent.—No, unless necessitated by inspection.
B. & M.—Yes.
B. & O.—No, unless necessitated by inspection.
N. H.—Yes.
N. Y. C.—No, unless necessitated by inspection.
Penn.—No, unless necessitated by inspection.
S. P.—No, unless necessitated by inspection.
C. M. & St. P.—No, unless necessitated by inspection.

Question No. 11-A. What is your practice in this respect?

C. N.—Not unless necessary.
N. & W.—Not unless necessary.
Mich. Cent.—Not unless necessary.
B. & M.—Commutators turned and undercut.
B. & O.—Not unless necessary.
N. H.—Commutators turned and undercut.
N. Y. C.—Not unless necessary.
Penn.—Not unless necessary.
S. P.—Not unless necessary.
C. M. & St. P.—Not unless necessary.

Question No. 12. Do you consider it good practice particularly in case of low voltages control to remove coils and reinsulate when equipment is in for classified repairs, unless necessary as indicated by test or otherwise?

C. N.—No.
N. & W.—No.
Mich. Cent.—No.
B. & M.—No.
B. & O.—No.
N. H.—No.
N. Y. C.—No.
Penn.—Reply not definite.
S. P.—Yes.
C. M. & St. P.—No.

Question No. 12-A. What is your practice in this respect?

C. N.—Not unless necessary.
N. & W.—Not unless necessary.
Mich. Cent.—Not unless necessary.
B. & M.—Not unless necessary.
B. & O.—Not unless necessary.
N. H.—Not unless necessary.
N. Y. C.—Not unless necessary.
Penn.—Not unless necessary.
S. P.—Removed, insulated and tested.
C. M. & St. P.—Not unless necessary.

The first question raised at the 1923 convention was the practicability of attempting a uniform set of instructions for all classes of electric rolling stock. It is to be noted that this contention is substantiated by replies to question No. 1 wherein eight reply "Not practical," one replies "Yes," and one replies "Yes, but general."

Question No. 2 offers two alternatives: Separate instructions for each class, or a general form of instruction to which specific mileages, voltages and other features could be assigned to suit conditions. Four roads favor separate instructions, five favor general form instructions and one favors the adoption of last year's report.

From these expressions it would seem that the sub-committee should develop general instructions in which no specific figures are given, that would cover the various features involved and which could be used for the guidance of railroads in the adoption of electrification and as a basis of standardization by railroads now having electrification.

Questions No. 3 and 3-A cover the basis for establishing periods of inspection and repairs. Eight roads favor mileage, one favors hours or days in service and one favors input. Two others recognize power input as a factor, but consider mileage as more practical. The wide variation of mileages between periods of inspection and repairs indicates clearly the difficulty in establishing definite figures in this respect. This point is further borne out in the replies to Questions No. 4 and No. 5.

The necessity for daily inspection was another point under discussion. Five favor daily inspection and five do not; however, one mentions engineer's report and another suggests inspection at completion of road trip.

There is some question as to the extent of this operation. Undoubtedly all roads practice the customary terminal inspection and a more or less perfunctory electrical inspection to determine whether or not the equipment responds to the various control operations, while on the other hand it is doubtful if any make elaborate or extensive inspections approaching that prescribed for general inspection. Therefore, it would seem that all would be reconciled to a light inspection designated as terminal or trip inspection rather than daily inspection if it were understood that this involved merely such work as just discussed.

The question of test voltages and the method of making insulation tests is worthy of a great amount of study and research and it seems undesirable to attempt to prescribe definite values and practices in this instance. It would seem more logical to merely indicate the periods at which it should be done and the apparatus to which it should be applied. It might be well in passing to recommend it for further study as a special sub-committee assignment.

Replies to Questions No. 9, No. 10, No. 11 and 12 indicate quite clearly the practice in removing apparatus in whole or in part at times of general repairs. It is quite evident that this is not the general practice unless inspection indicates necessity for repairs or adjustments.

With the better understanding of the points in question it does not seem impratical to outline a general form of instructions for maintenance and inspection that would be applicable in all cases and of value to those interested in electrification.

Exhibit "B"—Report of Sub-Committee on Operating Problems Encountered in the Handling of Long Freight Trains Under Electric Operation on Heavy Grades

In the event of electrification to a portion of an existing steam operated railroad, it is to be expected that certain changes in methods and practices will be necessary, and it is the discussion of such features that the committee has undertaken. Information on this subject has been derived from the experiences of railroads in the United States whereon electric traction in mountain territory has been in use for several years. In each case the immediate results have been increased tonnage per train and increased train speed. These two things, whether brought about through the use of more powerful steam engines or with electric locomotives, will in themselves produce certain problems. Communication between head and rear ends of trains will be more difficult and the slack action will be more pronounced. As a matter of fact, these features are more easily overcome in the case of electrification than under steam operation because electric locomotives produce a more uniform rate of speed and are subject to closer control.

The first step is the training of enginemen for the operation of the new type of motive power. This is not a serious task, provided it is undertaken systematically by a well-organized group of instructors. The first and most important thing is to eliminate all thought of mystery. The usual result of this work is the development of a set of instructions for enginemen, far in advance of any previous instructions of that nature for the operation of trains, as former practices were usually the outcome of personal experiences and not as a general thing set down in printed form.

In former years, when operating double-head or with pusher, it was the universal practice to signal by means of whistle blast, but with the increase of train lengths this method became more and more unsatisfactory. In mountain territory, with curves and tunnels and with the long trains hauled by electric power, the whistle blast is entirely inadequate, therefore, it becomes necessary to develop some other means of signalling. The method now used in electrified territories of signalling with slack action through the train, while not altogether peculiar to electric operation, it being used in some steam operated territories as well, is much preferable to the former practice and produces a much smoother train operation.

There is no difficulty involved nor is there a serious burden placed on the operator in the control of trains on descending grades through regenerative braking, in fact, the operator's task is greatly lessened for it is merely a matter of proper manipulation of his control and he is always in possession of an additional factor of safety from the air brakes with a fully charged train line. The only existing problem is that of impressing upon the motormen the necessity for the same care to insure air-brake operation as with steam operation.

With the thought that a limited description of the practices prevailing on electrically operated heavy grade sections of existing roads would give interesting illustrations of some of the features peculiar to this subject, there have been incorporated in this report articles giving special items of interest relating to heavy grade operation on the Chicago, Milwaukee & St. Paul, the Norfolk & Western and the Baltimore & Ohio. These three instances represent the principle experience in heavy grade operation in this country. The Pennsylvania, while they do have some electric pusher service operation, did not care to contribute, explaining that their experience to date should be considered only as experimental. Other electrifications do not involve heavy grade operation to a major extent.

Chicago, Milwaukee & St. Paul Railway Company

The Chicago, Milwaukee & St. Paul has 647 miles of main line electrification. Two territories are involved, the first, which embraces the Rocky Mountain & Missoula Divisions, beginning at Harlowton, Montana, extends westerly for a distance of 439 miles to Avery, Idaho; and the second, embracing the Coast Division, begins at Othello, Washington, and extends westerly a distance of 208 miles to Tacoma, Washington. These two sections of electrification include practically all of the mountain grades of this railroad, the 220 miles intervening between Avery, Idaho, and Othello, Washington, being a comparatively low grade territory. This electrification embraces five mountain ranges wherein prevail steep grades and heavy curvature.

All train operation on the Rocky Mountain & Missoula Division is entirely done with electric power; and with the exception of a few branch line runs and some joint operations, the same statement holds true for the Coast Division. Trunk line movements of trains prevail, both passenger and freight trains being hauled in through train movements with little change in consist of train.

Tonnage Ratings. The following tabulation will indicate the tonnage handled over the various sections of the electrified territory according to the ratings of the locomotive in use:

Rocky Mountain & Missoula Divisions
Freight Service

East Bound Out of	Ruling Grade	Freight Motor Rating in Tons
Avery	1.7+	1450—2900 With Helper
East Portal	1.7—	2400*
Haugan	1.0—	C.L.*
St. Regis	0.4+	4100
Deer Lodge	0.6+	3300
Newcomb	1.6+	1500—3000 With Helper
Donald	2.0—	2000*
Piedmont	0.3—	C.L.
Lombard	1.0+	2500
Loweth	2.0—	2000*
Bruno to Harlowton	1.0—	4600*
West Bound Out of		
Harlowton	1.0+	2500
Bruno	2.0+	1250—2500 With Helper
Loweth	1.0—	5300*
Lombard	0.3+	4700
Piedmont	2.0+	1250—2500 With Helper
Penfield	1.7—	2500*
Newcomb	0.6—	4500*
Deer Lodge	0.4—	C.L.
Missoula	0.4+	4500
Alberton	0.4—	C.L.
St. Regis	1.0+	2900
Haugan	1.7+	1450—2900 With Helper
Roland to Avery	1.7—	2400*

Coast Division

East Bound Out of	Ruling Grade	Freight Motor Rating in Tons
Tacoma	0.3+	5000
Black River Junction	0.8+	3000
Cedar Falls	1.74+	1400—2800 With Helper
Hyak	0.7—	5000*
Kittitas	1.5+	1500—3000 With Helper
Boylston	2.2+	3000*
Beverly to Othello	0.4+	5000
West Bound Out of		
Othello	0.4—	5000
Beverly	2.2+	1100—2200 With Helper
Boylston	1.5—	5000*
Cle Elum	0.7+	3000
Hyak	1.74—	3600
Cedar Falls to Tacoma	0.8—	5000*

Note—Plus (+) indicates ascending grade, minus (—) descending grades.

Star (*) indicates regeneration. C.L.—Car Limit.

Characteristics of Locomotives in Freight Service.

Wheel Arrangement	4-4-4-4-4-4
Total Weight	576,000 pounds
Tractive Effort—30% adhesion	135,000 pounds
Tractive Effort, 1 Hr. Rating	84,500 pounds
Tractive Effort, Continuous Rating	70,700 pounds
Speed at 1 Hour Rating	15.25 M. P. H.
Speed at Continuous Rating	15.9 M. P. H.

Helper Service. Helper locomotives are used on eastbound tonnage trains out of Cedar Falls, Kittitas, Avery and Butte Yards, and on west bound tonnage trains out of Piedmont, Haugan and Beverly. 2500 ton trains are handled with one locomotive on the 1% grade west bound out of Harlowton and the train is doubled over the short 2% grade between Bruno and Loweth. This has been proven to be more economical than to maintain a helper station at Bruno. On the grades out of Piedmont and Butte Yards, Haugan and Avery, Beverly and Kittitas, the helpers are usually carried over the summit and down to helper station on other side in order to help out in regeneration and be in position to help train of opposite direction back over the grade.

In the operation of helpers, the helper locomotive is placed in the center of the train to as nearly as possible equalize the tonnage. This practice has been found to be desirable to eliminate excessive draw bar strain and to overcome derailments from the tendency of buckling the train.

The handling of tonnage trains on grades and curves with locomotives placed at head and middle of train has been satisfactorily accomplished by readily interpreted signals transmitted through the train. When starting a train, the lead locomotive begins to pull and the engineman of the second locomotive, when he perceives the slack going out, applies power to his locomotive, thus starting the rear half of the train and accelerating at approximately the same rate as the lead locomotive. If the electric pusher were to push the train up onto the lead locomotive and hold the train until the lead locomotive was ready to proceed, as is customary in steam operation, the electric equipment on the helper would be subject to an unnecessarily and probably injurious overload.

Testing Train Lines With Head and Rear Ends Obscured From View. In the electrified territories, there are numerous tunnels and many curves, making it impractical to depend upon hand or light signals entirely, therefore the following method was devised for testing brakes at the summit of grades before making the descent.

When approaching the summit of the grade, train is permitted to stop of its own accord and the engineer on the leading engine makes a ten to twelve pound reduction of brake-pipe pressure; this is noted by the trainman in the caboose who in turn increases this brake-pipe reduction by gradually opening the brake-pipe valve in the caboose until a full service application is made or a total of twenty or twenty-five pounds. This gives assurance to all concerned that the brakes may be applied from either end of the train and are operative throughout.

Control of Slack. The most necessary task in successfully operating freight trains is the control of the train slack in or out slowly and without severe shock. A correct understanding of this feature of handling and ability to control accordingly results in successful operation.

The time element is an all-important element and the control operations should not be hurried. This applies in starting, stopping or changing from motor regeneration or vice versa. To successfully stop freight trains, there should be no change in train slack during the time train brakes are applied as the slack should be run in before the train brakes are applied and engineer's brake valve manipulated in a manner that will result in slack remaining run in until the train is brought to a stop.

Reasonably Rapid Acceleration Desirable. The current required to start a tonnage train, particularly on heavy grades, is high and the train should be brought up to speed as quickly as practicable (within 15 to 20 minutes), in order to prevent damage to the electrical apparatus, especially the resistance grids. It is also more economical to utilize the electrical energy for accelerating the train to the free running speed than to dissipate it in the resistance through which the current must pass while the controller is on the intermediate notches.

Regenerative Braking. When starting regenerative braking some care is necessary on the part of the engineman to avoid severe shock, due to train slack. The most practical and safe method of starting regeneration, is to make a train brake application and while this is effective make the adjustment of levers so that regenerative braking will start slowly to be effective, being governed by the speed and indication on ammeters as to the proper time to release the train brakes. The retaining valves then gradually leaking off their holding effect, permits regenerative braking to be gradually increased to full effect without undue shock to train and without causing line surges in trolley voltage. In starting from summit of grade, at slow speed and before regenerative braking is started, a train brake application is made to determine the holding power of the brakes while actually under motion. This gives those in charge the assurance of ample braking power for a possible emergency.

Overheated and cracked wheels are almost unknown in our electric operated territory, trains making a continuous and unvarying movement from summit to foot of mountain grades.

In the event the regenerative braking features should fail, which is a very rare occurrence, trains may be controlled by air brakes in the usual manner, making use of all retaining valves, and practicing the "short cycle" method of braking. This so-called "Short Cycle" method, meaning frequent applications and releases of train brakes, leaving it up to the brake cylinder pressure retained by the retaining valves to control the speed of the train for a greater portion of the time.

Special Rules. Special rules and instructions have been developed with the adoption of electric traction, a great many of which being necessary of course for the guidance of the enginemen, electing to operate the electric motors. However, it further develops that many practices in the general operation of trains have been specifically established to the betterment of all train operation.

Norfolk & Western Railway Company

The electric operation of long freight trains on the Norfolk & Western consists principally of handling heavy coal trains at comparatively slow speeds over what is known at the Elkhorn Grade, crossing the Allegheny Mountains in McDowell County, West Va. The service consists in hauling empties westbound from Bluefield to the coal fields, delivering them to the mines and hauling loads back over the Eastbound grade and on to Bluefield, the eastern terminus of the electrification.

Physical Characteristics. The electrified territory extends from Bluefield, W. Va., to Farm, W. Va., a distance of approximately 40 miles and consists or grades varying from 0.4 percent to 2.3 percent. Fifty percent of the main line within the electrified zone consists of curves varying from 3 to 12 degrees, while the mine operation tracks run as high as 16 degrees curvature. Within a section of 10 miles between Kimball, W. Va., and Switchback, W. Va., there are approximately 54 main line switches controlling movements to mine operations. In addition there are some 20 crossovers between the East and Westbound main line tracks within the same 10 mile section.

Locomotives.

Type	2—4—4—2 + 2—4—4—2
Total Weight	600,000 pounds
Tractive Effort, 30% Adhesion	162,000 pounds
Tractive Effort, 1 Hour Rating	84,000 pounds
Tractice Effort, Continuous Rating	68,000 pounds
Speed, 1 Hour Rating	14-28 miles per hour
Speed, Continuous Rating	14-28 miles per hour

Operation. A train of westbound empties out of Bluefield consists of from 80 to 100 cars representing about 2500 tons. The normal movement consists of one electric locomotive handling the train of empties from Bluefield to the coal fields. If it is a train of empties to be moved as far as the electrification extends, or beyond, the train is operated at a speed of 28 miles per hour from Bluefield to Bluestone; 14 miles per hour from Bluestone to Coaldale up the 1% grade, approximately 20 to 25 miles per hour regenerating from Coaldale to Eckman or to Kimball; then 28 miles per hour to the western terminus of the electrification.

If a train of empties is to be delivered to the mines located on the descending grades between Coaldale and Northfork, W. Va., it is operated down the hill at a slower speed, approximately 15 miles per hour regenerating. This allows the slack in the train to accumulate and bunch against the locomotive. Under such operation it is an easy matter to stop the train by use of the straight air brakes on the locomotive, regeneration ceasing after dropping below 14 miles per hour. In this way, undesirable shocks and surges in the train are materially reduced. If a portion of the train is to be taken to Northfork or beyond, the speed from the last set off point, continuing Westbound, is held at approximately 20 to 25 miles per hour regenerating.

Frequently electric locomotives are used to double-head time freight westbound trains hauled by Mallet Locomotives, the latter engines making the entire division run. In this case, the electric locomotive is placed ahead of the steam locomotive; regenerating on the grade, holding the Mallet engine and train at approximately 20 to 25 miles per hour.

Under normal operation, there are, approximately, 2500 tons of westbound loads assembled daily at Flat Top Yard from nearby operations. These loads are picked up currently and handled by the electric locomotive in trains of empties and are handled to the Western Terminus of the electrification.

Eastbound Freight Train Movement. The eastbound movement consists of hauling approximately 40 cars, 3250 tons eastbound from Eckman to Bluefield, W. Va. Out of Eckman there is one electric locomotive pulling and another electric locomotive in the rear up the 2 per cent. compensated grade through Elkhorn tunnel at the summit of the mountain. From this point the pusher returns light to the foot of the grade and either assists in gathering up loads or takes its turn in pusher service, depending upon the number

of trains moving. From Coaldale, or a point just beyond the east portal of the tunnel, the train proceeds, hauled by one locomotive, to Flat Top, a small assembling yard about 8 miles west of Bluefield—where the train is filled out to 4700 tons, that being the tonnage readily handled by one locomotive from Flat Top to Graham. At Graham a point within three miles of Bluefield, an electric pusher again gets behind the train, assisting it up the grade to Bluefield. The run from Eckman to Bluefield is made at a constant speed of 14 miles per hour, both up and down grade—a distance of approximately 24 miles.

Starting from rest at Eckman, with a train of 3250 tons, one electric locomotive in the lead, and an electric pusher, the two locomotives will accelerate the train up to a speed of 14 miles per hour in approximately one and one-half minutes. To accelerate the train at this rate, a maximum power demand of 12,000 kilowatts is required.

In handling or making up the train tonnage enroute eastbound, it is the practice to fill out the train at both the head as well as the rear end, and as there are normally two locomotives—a lead and a pusher—it is the practice to keep either one or the other coupled to the train to insure efficient operation.

Operation With Helper Locomotive. In starting it is customary for the lead locomotive to drop back against the train, bunching the slack against the pusher locomotive. As soon as this bunching of slack is felt at the pusher locomotive, the enginman on the pusher begins to apply, steadily increasing it until he has maximum accelerating current on the motors. The enginman on the locomotive, to whom this starting impulse is readily felt, reverses his locomotive and commences to pull. The lead locomotive thus takes up the slack, picking up the train, car by car, until the load has been sufficiently balanced between the lead and the pusher locomotive to accomplish an easy moving off of the train.

The locomotives are equipped with relays which limit the current applied to the motors during acceleration and the engineman regulates the rheostate so that the current is kept up to this limit.

Approaching a stop signal, the enginman on the lead electric locomotive reduces speed, which results in the load building up on the pusher locomotive, and this is an indication to the engineman on the pusher that the engineman on the lead locomotive desires to stop and acts accordingly, by gradually reducing the power and speed developed by the pusher. In this way the pusher locomotive keeps the train bunched, which is in the interest of making a better start.

When the train has reached the summit and begins to descend the grade, the load on the lead locomotive gradually decreases as the train passes over the summit. When approximately half of the train is over the summit the speed gradually increases until it reaches about 15 miles per hour, when regeneration comes into action. The uncoupling lever between the caboose and the pusher locomotive has by this time been lifted and as the train passes over the crest of the grade it leaves the pusher. The pusher drops back, crosses over to the westbound track and returns to the foot of the grade.

Regenerative Braking. Under certain conditions, when the rails are wet and slippery, it is sometimes the practice to bring the air brakes into action while the locomotive is still braking by regeneration. When this occurs, the engineman makes a reduction of approximately 5 pounds in brake pipe pressure, which applies the brakes on the train, at the same time keeping them released on the locomotive.

General Operation. Should a break-in-two occur on the grade which is rare, but a contingency, the engineman on the lead locomotive makes an effort to release the brakes, which had been automatically applied, and continues to pull the train until stopped by the brakes on the train. The effort of the pusher engineman would be to promptly stop his section of the train, which however, is no different from what obtains in steam locomotive operation.

In the event of a power failure on an up-grade when a train is being hauled by a single electric locomotive, the train gradually slows down to rest.

In the event of a power failure with an electric locomotive pulling, assisted by a pusher, the load on the pusher locomotive is gradually picked up, car by car, until the current consumed by the pusher locomotive motor reaches the predetermined value at which the circuit breakers have been set to open, resulting in the train coming to rest.

In the event of a power failure of an electric locomotive in the act of pushing, the load will automatically begin to build up on the lead locomotive, car by car, until the current being taken by the lead locomotive reaches a value sufficient to trip the circuit breakers; and by setting the circuit breakers to trip within a reasonable limit, the chance for a break-in-two under such conditions is remote.

Whenever the power begins to build up on either the lead or pusher locomotive, under such conditions, the enginceman sees that the locomotive is developing more power than is required under ordinary operating conditions, or that the slack is running in or out and immediately shuts off before the locomotive tractive effort builds up to an undesirable amount.

Baltimore & Ohio Railroad Company

That portion of the Baltimore and Ohio Railroad which is electrified lies within the City limits of Baltimore, and is a part of to so-called Belt Line, extending from Camden Station on the west to Waverly interlocking tower on the east, a distance of 3.75 miles. There are eight tunnels in this zone together amounting to 48% of the total distance, the longest tunnel, which is between Camden Station and Mt. Royal Station, being 7,300 feet in length. This tunnel contains two tracks while there are four tracks between Mt. Royal and Huntington Avenue from which point to Waverly there are two tracks. This part of the zone through which trains are handled by electric locomotives is entirely on a grade, the difference in elevation amounting to 150 feet which gives an average through grade og 0.9%, the ruling grade being 1.52% and the maximum curvature 10 degrees, 16 minutes.

Locomotives.

Type	0—4—4—0
Total weight	242,000 pounds
Tractive effort at 30% adhesion	72,600 pounds
Tractive effort, 1 hour rating	32,000 pounds
Tractive effort, continuous rating	19,400 pounds
Speed, 1 hour rating	12.75 miles per hour
Speed, continuous rating	14.5 miles per hour

Ruling Grades, Tonnage Rating and Operation. The electric service in this territory is very similar to steam helper locomotive service, except the road steam locomotives they might be helping furnished no assistance.

The present maximum rating for freight trains handled over the Belt Line is about 2650 adjusted tons or approximately 2300 actual tons excluding steam locomotive weighing approximately 255 tons.

The ruling grade in the zone is 1.52% eastbound, while that of the remainder of the steam locomotive division to Philadelphia is but 8%. This requires the electric locomotives to develop practically twice the tractive effort of the steam locomotives. On account of the grade, the westbound movement, which is down-grade, operates through the zone without requiring power from the steam locomotives except for starting. The trains, therefore, are handled electrically in only the up-grade direction, the electric locomotives running light, which results in a unit power consumption which in all probability is larger than that for most of the existing steam railroad electrifications.

The traffic at present consists in the handling of about 33 trains eastbound daily. Of these there are probably 7 through passenger trains for the east, and one or two locals, the remainder being eastbound freight trains. On special occasions, a considerably greater number of eastbound trains are handled within a 24-hour period.

The report is signed by L. K. Silcox (chairman), general superintendent motive power, Chicago, Milwaukee & St. Paul Railway; J. A. Carmody, superintendent electrical equipment, New York Central Railroad; J. V. B. Duer electrical engineer, Pennsylvania Railroad System; G. C. Bishop, superintendent motive power. Long Island Railroad; A Kearney, superintendent motive power, Norfolk & Western Railway; W. L. Bean, assistant mechanical manager, New York, New Haven & Hartford Railroad; J. H. Davis, electrical engineer Baltimore & Ohio Railroad .

The personnel of the sub-committee which prepared exhibit A consisted of J. V. B. Duer (chairman), J. S. Carmody, L. K. Silcox.

The personnel of the sub-committee which prepared exhibit B is A. Kearney (chairman), L. K. Silcox, J. V. B. Duer, J. H. Davis.

Discussion

J. V. B. Duer (Pennsylvania): The statement is made in the report that it would be unreasonable to urge the discarding of direct current for alternating current or vice versa where a standard voltage has not yet been reached for either.

In regard to the alternating current system, there is a voltage at the present time which is practically standard on all the railroads using that system. As one of the users of the alternating current system, we believe that one of the great advantages is the possibility in the future of raising the voltage to whatever the demands of traffic may require, and I do not believe that either, insofar as the direct or the alternating current system is concerned, we will ever arrive at a standard voltage, because I believe that the requirements of the service will push the State of New York ahead and give us the voltage that we desire.

I do not think that it is a proper thing to standardize on either system but I do not regard the question of the voltage as having anything to do whatever with the question of possibility of standardization.

I am not entirely clear as to just what is intended by the statement that, "When comparing steam locomotives with electric locomotives, consideration is seldom given to the fact that the electric locomotive is usually designed with a much greater reserve of power than is the steam engine." I think it is usually the practice in designing electric locomotives to design them for the service in which they are to be placed with the idea of utilizing to the best advantage the weight on drivers. I do not believe that the electric locomotive has any greater reserve of power than the steam locomotive.

It is also stated that, "As traffic drops off and the load factor becomes low, then the system must operate at a disadvantage and assumes a situation which must support a large percentage of idle capital with no chance of transferring the reserve to other points to relieve periods of heavy traffic."

That applies only in cases of partial electrification. There is no reason whatever why any railroad with a system of electrification extending throughout a division or a series of divisions should not transfer power from one division to the other or from one end of a division to another in case the requirements of the case demand it. They would naturally provide in their power houses and substations the necessary capacity to take care of any load that that division might be called upon to handle. That would be a necessary capital investment which they would have to face and it would be available in case they had a surplus of traffic at one point and a diminution of traffic at the other point.

I do not think that the questionnaires on electric rolling stock have been considered in sufficient detail to permit of drawing any definite conclusions from them and these conclusions are not always justified.

In my opinion any instructions from which the specific figures are eliminated would be of little or no use to a railroad formulating instructions for its own conditions. I also think it is general practice to make the inspection of electric locomotives on a somewhat larger interval than on multiple unit cars.

In regard to the question of test voltages and the method of making installation tests, I do not agree with the statement that a special sub-committee assignment should be made of this subject. This question is so intimately associated with proper operation and maintenance of the electrical equipment of rolling stock that it should receive very careful consideration from the sub-committee.

It is very undesirable from a standpoint of a railroad to get the operating voltage too far below the test voltage; in other words, there is no use in trying to maintain the equipment in excessively good condition in regard to insulating values. It is also extremely undesirable to allow the equipment to get too far below where it should be. I know of several serious accidents which have resulted just due to the fact that the insulation tests were too haphazard.

Development of the Electric Locomotive

By Mr. F. H. Shepard
Director of Heavy Traction,
Westinghouse Electric & Manufacturing Company

This paper is one which will probably be carefully preserved by most of its readers. It presents a well-rounded picture of electric locomotive development. Practically every electric locomotive in the world, built or under construction, is tabulated and the wheel and cab arrangement of each type is shown in diagram. Advantages and disadvantages of each type of drive are described and illustrated. The information is presented in a simple form and the data collected has been condensed and arranged in a comparatively small table so that it is easy for the reader to get a comprehensive picture of the present status of electric locomotives in main line service. The compilation of this material represents much work and necessitated the sending of many letters and cablegrams. The author is to be congratulated for making a valuable contribution to the records of the American Railway Association.

F. H. Shepard

Electricity wherever used has led to improvement in methods, sometimes revolutionary; witness, illumination, urban and suburban traction, machine shop practice as well as certain of the metallurgical and chemical industries. The natural suggestion for railroad electrification has therefore been appealing and the subject of much popular discussion; but, notwithstanding the first real use of electric locomotives, which was in the Baltimore and Ohio Tunnel at Baltimore in 1895, the growth of railway electrification in America has been relatively slow.

The reasons therefore may be taken as

1st. The relatively high capital expenditure required and the recent difficulties of railroad finance.

2nd. The plentiful supply and the relatively low cost of coal.

3rd. The lack of general understanding or definition of objectives for future railroad service.

Electrifications to date have generally, in most countries, been made to meet some abnormal situation, local condition or local restriction, which required special consideration. In all these cases, the special object has not only been attained but the service has been markedly improved over that of the steam service replaced. Even with these limitations, electrifications throughout the world have accomplished much in development and progress, especially toward indication of values for future transportatoin needs.

The consideration for a more extended application to the various classes and conditions of railroad operation and to their modification and improvement has not been as great as indicated results and advantages, immediate and future, when analyzed, would seem to have warranted. This is essentially due to the difficulty in securing funds which has halted all major railroad improvements

during recent years. For the immediate future, great and exactly calculable economies are too often the sole requisite and, owing to the difficulty of evaluation, little consideration is given to the less tangible immediate advantages and to those relating to development of position for future requirements and growth.

Such requirement for immediate financial advantage does not generally govern when consideration is given to track revision or additions, enlargement or modification of terminals, additions to shops, equipment and many other desirable programs which come under the general heading "Additions and Betterments of Property," but it appears that when electrification is considered, too often conditions of the moment or of the immediate future are those which control. Where in the accomplishment of gerat progress or in the development of great strength or position in any industry has so limited a view prevailed?

The United States with its great distances, is what it is because of Rail Transportation and its position in the future will depend upon Rail Transportation.

It is coming to be accepted more and more that the future role of the railroads will be that of wholesalers of transportation.

TABLE I

SUMMARY

APPROXIMATE SURVEY OF ELECTRIC LOCOMOTIVES – BUILT AND BUILDING 1924

	D C HIGH VOLTAGE						A C SINGLE PHASE				
	No	Aggregate Wt Thousands of Lb	Aggregate HP (one-hour)	Lbs per HP	Average Wt per Locomotive		No	Aggregate Wt Thousands of Lb	Aggregate HP (one-hour)	Lbs per HP	Average Wt per Locomotive
BRAZIL	21	4 196	31 060	135	200 M lb						
CANADA	6	996	7 680	130	166		6	792	4 500	176	132 M lb
CHILE	42	8 446	68 420	124	201						
MEXICO	10	3 090	27 360	113	309						
UNITED STATES	131	37 863	247 300	153	289		199	57 645	359 450	161	290
TOTAL AMERICAN	210	54 591	381 820	143	260		205	58 637	363 950	161	286
AUSTRIA							84	12 259	99 250	124	146
ENGLAND	11	1 898	12 800	148	173						
FRANCE	336	53 885	538 300	108	160						
GERMANY							290	61 029	486 054	126	210
NORWAY & SWEDEN							136	25 370	153 880	166	188
SPAIN	12	2 220	19 320	115	185						
SWITZERLAND							207	43 514	371 980	117	211
TOTAL EUROPEAN	359	57 923	570 420	102	162		717	142 377	1 111 144	128	199
JAPAN	42	5 942	55 420	107	142						
JAVA	6	840	8 300	101	140						
NEW ZEALAND	5	337	3 400	158	107						
SOUTH AFRICA	78	11 400	93 700	122	146						
TOTAL OTHER COUNTRIES	131	18 719	160 820	117	143						
TOTALS	700	131 233	1 113 060	118	188		922	201 009	1 475 094	137	218
	D C LOW VOLTAGE						A C THREE PHASE				
ARGENTINA	2	295	1 840	160	148 M lb						
UNITED STATES	128	31 815	261 090	122	246		4	920	6 000	153	230 M lb
TOTAL AMERICAN	130	32 110	262 930	122	247		4	920	6 000	153	230
ITALY	10	1 520	13 600	112	152		492	76 580	1 197 730	64	156
SWITZERLAND							6	913	9 369	98	152
TOTAL EUROPEAN	10	1 520	13 600	112	152		498	77 493	1 207 099	64	156
TOTALS	140	33 630	276 530	122	240		502	78 410	1 213 100	65	156
GRAND TOTAL D C	840	164 863	1 389 590	119	197	GRAND TOTALS A C	1424	279 419	2 688 194	104	196

This means the mass movement of traffic. With such mass movement will come ordered or scheduled movement, thereby obtaining greater use of equipment and facilities, higher speeds, larger trains, and greater despatch through terminals. It is hard to see how the continued growth and prosperity of industry in America can otherwise be obtained.

Electricity, due to its economy and future universality of generation, its ease of distribution and the flexibility of its control and use, is the outstanding agency through which this result will be secured. Instead of employing distributed generation of power to transport and move trains by the many small steam units with their great limitations in capacity (hence, in their speed, tractive effort and acceleration) electrification permits the centralization of power generation with absence of such limitation to capacity and no such limitations to tractive effort, speed and acceleration. Furthermore, there is the advantage that the power can be instantly available when and where most needed, over a great range of distance within economical transmission, and, when not needed, is shut off without continued standby losses. Electrification is coming to be realized more and more as the tool for such transpjortation service. Compared with the past, it may be predicted that more generally in the near future and always in the long future its consideration for Additions and Betterments of Property will obtain.

The electric locomotive can be one of relatively unlimited capacity as to tractive effort or speed, or both. It can, for this reason, haul more tons over a given distance in less time than a steam locomotive, but, in addition, it will also be available for a much greater period of time, for experience has shown the possibility of obtaining a serviceability factor approaching 90%.

The foregoing has been conclusively demonstrated by experience with such locomotives as have been built since and including the first pioneer installation at the Baltimore and Ohio Tunnel, and this irrespective of application, of type. or the electrical or mechanical system used.

There are at present in existence or under construction, over 2,200 electric locomotive units, aggregating some 4,000,000 horsepower, for every class of service excluding those which may not readily be classed as main line locomotives. Table 1 shows their distribution, nominal horsepower, capacity, their weight and the electric system used.

It will be noted that of the aggregate number and horsepower—

6.2%	in number and	6.7%	in horsepower are	low	voltage d. c.
31.0%	" " "	27.3%	" " "	high	" " " .
40.6%	" " "	36.2%	" " "	single	phase a. c.
22.2%	" " "	29.8%	" " "	three	" " " .

Of the high voltage d. c. locomotives, 18.7% are in the United States and 48% are in France.

Of the single phase locomotives, 21.6% are in the United States, the remainder being in continental Europe.

Of the three phase locomotives, 98% are in Italy.

The permissible length of this paper precludes the possibility of description in detail of the development of the electric locomotive. The steam locomotive during its career, a century long, has in general broadly followed along its original lines of design, necessarily so by reason of its very nature. The main and controlling element of a steam locomotive is its boiler and around it is designed the attachment and grouping of cylinders, frames, running gear and the other elements. The reason for this is that a steam locomotive generates its own power and in addition to being an engine for developing drawbar pull, it carries its own power plant. It is, therefore, circumscribed as to size and restricted as to wheel arrangement, placement of cylinders and general configuration. The electric locomotive, on the other hand, does not generate its own power. It is only an engine for developing draw-bar pull which transforms or converts external power. Its tractive effort originates at its motor or motors and by the mechanical connecting devices is transmitted to the drivers. The other equipment is merely adjacent to the motors and may be carried by the locomotive frames or cab structure or by both. There may be any number of driving motors, large or small, all under common control. It is possible to design an electric locomotive around any one of its elements and with major variations almost without limit. This great latitude with which design can be accomplished secures many advantages but likewise imposes the difficulty of decision as to the best amongst the various types.

It will be seen that steam locomotives have a comonm resemblance to each other and permit of comparatively simple classification, analysis and decision, whereas with electric locomotives there may be but slight resemblance which manifestly imposes difficulties in classification and broad discussion. It should be apparent also that any broad generalization as to electric locomotive developpment must necessarily be more or less arbitrary; but the writer believes, however, that an historical tabulation of types with certain data and explanation best fulfils the purpose of this paper.

Methods of Electrification

The use of electricity as a source of power pre-supposes a conducting system and a contact system parallel to the rails. There is now general agreement, in America at least, that this latter should be overhead and at high voltage. This may be alternating current or direct current. Each has its own advantages and each together with the particular service contemplated governs the general type and details of the motive power or locomotive used.

Table II shows the various methods of electrification classified as to kind of current supplied by the contact system, each system with its various and alternate possible arrangements. This shows the provisions necessary for electric supply to the locomotives, and, for the locomotives, in turn, different and alternate selections of equipment. It is seen that the greatest range of selection obtains with the single phase system. Conclusion as to the most desirable system will, however, be determined not by conditions pertaining to locomotives alone, nor to power supply alone, but by the relative importance of each and, especially, will always be governed by the overall objective—the most effective use of the railroad.

Except for purely local conditions which prevail for some services, such as subway and elevated and for such conditions as may be permissible in England, the use of low voltage direct current

is not now given practical consideration for extended electrification. The three phase system is contemplated by the requirement for two separately insulated contact wires over each track. It is also limited in voltage. For these reasons, notwithstanding its highly successful operation and its advantages in locomotive weight— efficiency, no adoption or extension of this system is taking place except in Italy where a large and comprehensive expansion is under way. There remain then the other two systems for heavy traction, high voltage direct current at 1,500 to 3,000 volts, and single-phase alternating current at 11,000 to 22,000 volts or higher.

The advantage of high voltage, wherever used, is to increase the range of distance for the economical use of electric power. Relatively speaking, the higher the voltage on the contact wire the less number of generating stations if power is fed direct, or substations with the usual indirect feed. The effective use of transforming or converting apparatus at substations as determined by the size and frequency of train operations, establishes the relative cost and economy of the voltage selected, and thereby the system.

speeds, without undue stresses in its own structure or that of the permanent way, and without undue wear of rail or tires. The primary objective of the design is, of course, to secure both a good engine for developing draw-bar pull and a good vehicle. This is relatively simple when operation is limited to low speeds and with little critical curvature. When, however, high speeds or high speeds with critical curvature, in addition to the two-way operation, must be provided for, it becomes less simple, even with the great latitude in design and the possible combinations which the electric locomotive permits. The result is usually a compromise between what might be called the best engine of traction and the best vehicle.

A large motor may drive more than one axle, in which case there is required a side rod drive direct or through gearing, or a number of small motors may each drive a single axle through a direct connection or through gearing. Guiding or idle axles may or may not be used depending upon the speed, curvature and track stress or axle loading permissible.

The motive power units under common control which is, by the

TABLE II

RAILWAY ELECTRIFICATION SYSTEMS

SYSTEM	PRIMARY		SECONDARY		LOCOMOTIVE
	Generation	Transmission	Conversion	Distribution and Contact	
Low Voltage D. C.	Heat or Hydro.....	3 phase at commercial or low frequency....	At substations. Transformers and rotary converter or M. G. set or rectifier..............	Heavy feeder and single overhead wire or Feeders and third rail....	Low voltage D. C. motors
High Voltage D. C.	Heat or Hydro....	3 phase at commercial or low frequency....	At substations. Transformers and M. G. set or rotary converter or rectifier..............	Heavy feeder and single overhead wire.........	High voltage D. C. motors M. G. set for auxiliaries.
Three Phase......	Heat or Hydro....	3 phase at low frequency....	At substations. Transformer..............	Feeder and two separate overhead wires........	High voltage 3 phase induction motors.
Single Phase......	Heat or Hydro....	3 phase at commercial frequency......	At receiving station. Frequency changer or phase balancer; and At substations. Transformer................	Small or no feeder and single overhead contact wire.............	Low voltage 3 phase induction motors with phase converter and transformer or Low voltage single phase motors and transformer or Low voltage D. C. motors with M. G. set or rectifier and transformer.
		Single phase at low frequency	At substations. Transformer................		

It should be noted that of the countries which are definitely embarked on electrification programs, France, Holland and Japan have decided in favor of standardizing on 1,500 volts direct current, Chile at 3,000 volts and South Africa at both 1,500 and 3,000 volts, while Switzerland, Sweden, Norway, Germany and Austria have standardized on single-phase at 16,000 volts.

England is extending its present single-phase installation, its low voltage direct current installations and also intends to use 1,500 volts direct current.

In the United States one of the existing installations of low voltage direct current is being extended, one at 1,500 volts direct current is authorized, three existing single-phase installations are being extended, and an additional one is under construction.

Reference to column locomotive, Table II, will show the major elements required on the locomotives for the various systems. As these differ, the design of locomotive differs as to number and size of motors, their mounting and connection to each other and to the driving mechanism for propulsion. The type, amount, size and weight of the electrically connected equipment may vary widely. This, in turn, influences both the locomotive structure and wheel arrangements.

General

An electric locomotive, like a steam locomotive, has two main functions—that of an engine for developing draw-bar pull and that of a vehicle. Its purpose is to develop tractive effort from standstill to and at certain speeds. In order to do so, it must be able to run safely over the track, tangent or curved, at those

way, a proper definition of an electric locomotive, may have a single wheel base, or an assembly or short or long wheel bases, coupled together by cab or by hinges or by draw-bars. Each individual unit may have or may not have auxiliary trucks for guiding or for bearing weight. Each unit may be an independent vehicle or it may be a vehicle whose guiding or stability is effected by the preceding or following unit through hinges. The cab structure may be integral with the locomotive frame or it may be independently borne, and attached to two or more wheel bases.

It should be borne in mind that the mechanical parts form the link between the electrical apparatus and the track and the adequacy of their detail design and the proper characteristics of the whole are essential to the success of an electric locomotive.

How these various possible forms have been made use of to meet the various requirements and the various practices which have been evolved, is shown by Table IV, A & B which gives the date of construction, detail of type, capacity and the more important data of substantially all locomotives built or building up to date.

Conclusions drawn from these data must be made with a full consideration of all the critical factors involved. The table may contain certain errors and omissions but is deemed, nevertheless, sufficiently accurate to indicate broadly the development of the electric locomotive. It should be noted that the tabulation includes certain experimental locomotives built solely for development purposes in Germany and Switzerland prior to their adoption of extensive electrification programs.

The table might be taken without explanation as complete as

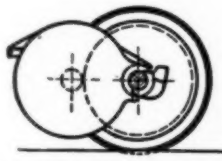
to types of motors and the different drives, excepting for the causes which influence and the reasons which govern their selection. Therefore, specific references to the various uses and practices follow.

Within certain limits the electric system adopted and the service for which the locomotive is intended are the chief factors which will govern the fundamental design of electric locomotives. The electric system chosen together with the service requirements will determine the type of motor, its characteristics and its size and speeds. The type of motor and restriction to driver weights will determine the drive within limits of narrow choice; and the drive will, in turn, together with the absence or presence of critical curvature essentially determine the configuration of the rigid running gear. The necessity for auxiliary trucks will be determined mainly by the service requirements, chiefly that of speed, and presence or absence of critical curvature; but, in certain cases, will be determined or influenced by the limit of axle loading or by placement of driving motors or placement and amount of auxiliary apparatus.

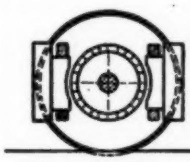
TABLE IIIA

TYPES OF DRIVE

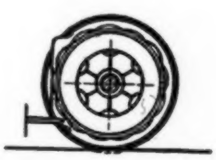
Individual Drives



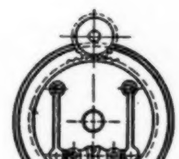
(a) Axle hung nose suspended motors single reduction, solid or flexible, single or twin gears.



(b) Direct gearless drive with the armature mounted upon and integral with the axle; the motor field integral with the locomotive frame.



(c) Direct gearless quill drive, the armature mounted on a quill surrounding the axle, the connection to wheels through spring elements, permitting relative vertical movement; motor field mounted on locomotive main or truck frame.



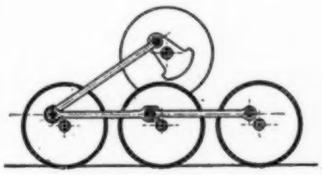
(e) Geared flexible drive with motors frame-mounted, with or without quill gear connection through a flexible universal driven wheel, to permit relative vertical movement between motor and axle.

(d) Geared quill drive, the motors and quill frame-mounted; the quill surrounding the axle carrying the gear, connection to the driven axle through springs or mechanically flexible elements, these permitting relative vertical movement between motor and axle.

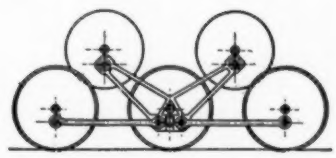
TABLE IIIB

TYPES OF DRIVE

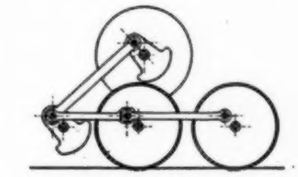
Collective Drives



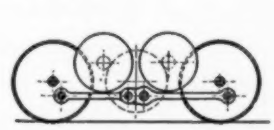
(f) Direct side rod drive by which the torque is transmitted from the motor shaft by direct rod connection to the driving wheels.



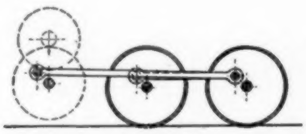
(g) Direct drive with Scotch yoke by which the transmission of torque to wheels is effected directly from the motor or motors, arranged to permit independent vertical movement of the driving pin and bushing.



(h) Jack shaft side rod drive by which the torque is transmitted from the crank of one or two motor shafts through a main rod or rods to a jack or auxiliary shaft or shafts, and from the latter to the wheels through side rods. The connection from jack shaft to side rods may be direct, or by yoke with or without flexible element.



(i-1) Geared jack shaft side rod drive by which the torque from the motor shaft is transmitted to the jack shaft by solid or flexible gears and from the jack shaft to wheels by side rods direct or by yoke.



(i-2) Geared jack shaft side rod drive similar to (i-1) except that the jack shaft is outside the driving wheels.

Types and Characteristics of Motors

The high voltage d.c. system requires the use of one type of motor, the d.c. series motor. The single phase system permits the use of the a.c. series motor, the a.c. induction motor and the d.c. series motor.

The direct current motor is the out growth of the street railway motor. The speed curve falls rapidly as the tractive effort increases, so that a maximum tractive effort is available at low speeds, whereas at high speeds the tractive effort falls. With the usual series motor the only practical way of controlling speed (except for the restricted range of field control) is by varying the voltage across the motor armatures. This is accomplished by use of external resistance and by changing motor combinations.

The limitations of design are influenced not only by speed and load requirements but by the need for stability against flash-over. This last is also affected by the conditions of current supply and

Figure I

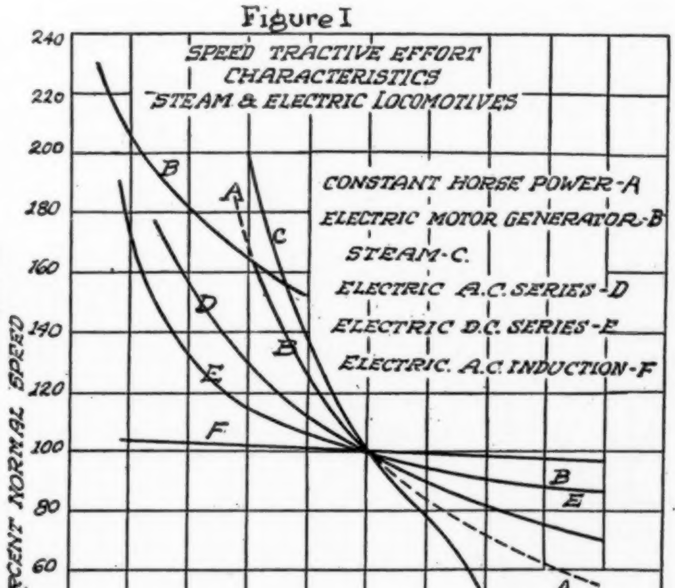


Table IV A. Direct-Current Locomotives

Continent	Country	Railway	Key No	Contact Line Volts	Contact Line Type	Gauge Inches	Year in Service	Number	Type of Serv	Axle Classification	Methods of Drive	Wheel Diam. Driver	Wheel Diam. Idler	Lgth Over All	Rigid Wheel Base	Weights Total	On Drivers	Per Driving Axle	Mech Parts	Elec Parts	One Hour HP	One Hour MPH	One Hour TE Lbs/1000	One Hour Wt per HP	Continuous HP	Continuous MPH	Continuous TE Lbs/1000	Continuous Wt per HP	Max Safe Speed MPH	Motors No	Motors Volts	Ventilation	Gear Ratio	Road No	Key No
America	Argentina	Buenos Aires & Western	1	800	BOTH	66	1916	2	Fr't	B-B	Gear	48	—	518	108	147.4	147.4	36.9	96.9	50.5	920°	18	19.2	160	528	24.6	8.1	28.3	46.7	4	775	F	18.70		1
	Brazil	Paulista	2a	3000	LINE	63	1921	2	Pass	1B+B1	Quill Gear	63	36	635	100	283.8	206	51.45	166.8	117	2400	42.8	20.96	118	1800	47.2	14.2	158	65	4 Twin	3000	F	28.86	212-3	2a
			2b	3000	LINE	63	1921	2	Fr't	C+C	Flex. Gear	40	—	602	168	234	234	39.05	145.45	88.85	1800	20.8	32.4	130	1350	23.4	21.6	173	42	6	1500	F	16.83	214-5	2b
			2c	3000	LINE	63	1921	4	Pass	2B+B2	Twin Gear Flex.	42	36	660	93	240	160	40.0	158.9	81.1	1680	40.5	15.68	143	1600	41.2	14.7	150	62	4	1500	S	30.70	200-3	2c
			2d	3000	LINE	63	1921	8	Fr't	B+B	Twin Gear Flex.	42	—	470	104	200	200	50.0	118.8	81.2	1680	20.8	30.6	119	1600	21.0	28.8	125	34	4	1500	S	18.82	204-11	2d
			2e	3000	LINE	63	1924		Sw.	BB	Gear	42	—			140	140														1500	F			2e
	Canada	Canadian National	3	2400	LINE	56½	1918	6	P&F	B+B	Twin Gear	46	—	448	104	166	166	41.5	102.54	63.46	1280	23.4	20.2	130	1090	24.9	16.3	152	50	4	1200	F	25.80	600-5	3
	Chile	Bethlehem-Chile	4	1200-2400	BOTH	56½	1917	3	Ore	B+B	Twin Gear	52	—	594	132	239	239	59.75	120.6	118.4	1370	12.2	42.0	249	1190	12.7	35.2	201	35	4	1200	F	18.82	678	4
		Chilean-State	5a	3000	LINE	66	1923	6	Exp P	1C+C1	Flex Gear	42	30	701	173	259.8	210	35.0	155.6	104.2	2400	36.0	25.8	108	2040	39.7	19.9	127	63	6	1500	F	21.56	2801-6	5a
			5b	3000	LINE	66	1923	11	Loc. P	B+B	Flex Gear	42	—	465	100	160	160	40.0	94.6	65.4	1640°	36.0	17.2	100	1360	39.7	13.2	118	56	4	1500	F	21.56	2501-11	5b
			5c	3000	LINE	66	1923	15	Fr't	C+C	Flex. Gear	42	—	597	165	230	230	38.3	140	90	1800°	21.5	31.2	128	1500	23.0	24.4	153	44	6	1500	F	15.63	2001-15	5c
			5d	3000	LINE	66	1923	7	Sw.	BB	Hel. Gear	42	—	480	102	137	137	34.25	82.5	54.5	640	10.5	23.0	214	384	12.7	11.0	357	35	4	1500	S	16.63	2301-7	5d
	Mexico	Mexican	6	3000	LINE	56½	1923	10	P&F	B+B+B	Flex Twin Gear	46	—	635	110	309	309	51.2	174	135	2736°	19.0	54.0	113	2520	19.5	48.5	123	40	6	1500		18.90	1001-	6
	U.S. of America	Baltimore & Ohio	7d	600	RAIL	56½	1923	2	P&F	B+B	Twin Gear	50	—	474	114	240	240	60	175	65	1100	16.4	25.0	218	670	19.6	12.9	352	45	4	600	F	24.78	15-16	
			7a	600	RAIL	56½	1903-08	4	Fr't	D	Gear	42	—	355	174¾	160	160	40.0	116	44	800	8.0	36.0	200						4	600	S	19.81	6-9	7a
			7b	600	RAIL	56½	1910	2	P&F	B+B	Twin Gear	50	—	474	114	185	185	46.25	119	66	1100	16.4	25.0	168	670	19.6	12.8	216	45	4	600	F	24.78	11-12	7b
			7c	600	RAIL	56½	1912	2	P&F	B+B	Twin Gear	50	—	474	114	200	200	50.0	135	65	1100	16.4	25.0	182	670	19.6	12.8	298	45	4	600	F	24.78	13-14	7c
		Butte-Anaconda & Pacific	8a	2400	LINE	56½	1913-17	26	Fr't	B+B	Twin Gear	46	—	448	104	160	160	40.0	100	60	1280	15.4	30.6	125	1090	16.2	25.0	147	35	4	1200	F	18.83	39-64	8a
			8b	2400	LINE	56½	1913	2	Pass	B+B	Twin Gear	46	—	448	104	160	160	40.0	100	60	1280	23.4	20.2	125	1090	24.6	16.2	147	50	4	1200	F	25.80	65-66	8b
									+ = Motive Power Unit																										
		Chicago Milwaukee & St. Paul	9a	3000	LINE	56½	1917-18	4	Sw.	BB	Gear	40	—	497	96	143.2	143.2	35.8	80.9	62.3	[illegible]	11.5	21.4	216	480	12.8	14.0	298	35	4	1500	F	17.64	10050-53	9a
			9b	3000	LINE	56½	1916	84	Fr't	2B+B	Twin Gear	52	36	672	126	288	225	56.25	164	124	1720	15.25	84.5	167	1500	15.9	70.7	192	35	4	1500	F	18.82	10200-41	9b
			9c	3000	LINE	56½	1920	5	Pass	1B+D+D+B1	Gearless	44	36	912	165	521.2	457.8	38.15	286.5	234.7	3500	27.1	48.5	149	3200	28.4	42.0	163	90	12	1500	F	—	10250-54	9c
			9d	3000	LINE	56½	1920	1	Fr't	2C1+1C2	Geared Quill	68	36	1063	201	600.0	378	63.0	367.2	232.8	4680°	22.6	78.0	128	3400	26.4	48.1	176	55	6 Twin	750/1500	F	21.92	10300	9d
			9e	3000	LINE	56½	1920	9	Pass	2C1+1C2	Geared Quill	68	36	1063	201	600.0	378	63.0	367.2	232.8	4680°	26.7	66.0	128	3400	31.2	40.8	176	65	6 Twin	750/1500	F	24.09	10301-09	9e
		Long Island	10	650	RAIL	56½	1917	1	Fr't	BB	Geared	56	—	474	86	175.8	175.8	43.95	114.6	61.16	1200	21.2	23.2	146	1000	26.7	15.4	176	56	4	650		22.70	323	10
		Michigan-Central	11a	600	RAIL	56½	1909	6	P&F	B+B	Twin Gear	48	—	474	114	200	200	40	135	65	1100	11.8	35.0	182	670	14.0	18.0	298	40	4	600	F	19.82	7500-5	11a
			11b	600	RAIL	56½	1914	4	P&F	B+B	Twin Gear	48	—	474	114	240	240	60	175	65	1100	12.3	34.0	218	670	14.0	18.0	358	40	4	600	F	19.82	7506-9	11b
		New York Central	12a	600	RAIL	56½	1906	35	Pass	2D2	Gearless	44	33	465	156	227.7	140.9	35.23	167.7	60.0	2200	38.5	21.0	103	800	60.0	5.0	284	80	4	600	S	—	1100-34	12a
			12b	600	RAIL	56½	1906-09	12	Pass	2D2	Gearless	44	36½	516½	156	244.5	148.5	37.13	184.5	60.0	2200	38.5	21.0	111	800	60.0	5.0	306	80	4	600	S	—	1135-46	12b
			12c	600	RAIL	56½	1913	10	Pass	BB+BB	Gearless	36	—	662	60	237	237	29.63	163	74.0	2320	50.5	17.2	102	1760	57.5	11.4	135	85	8	600	F	—	1147-56	12c
			12d	600	RAIL	56½	1914-18	16	Pass	BB+BB	Gearless	36	—	682	60	265	265	33.13	177	88.0	2600	49.0	20.0	102	2000	58.3	14.0	133	85	8	600	F	—	1157-72	12d
		Pennsylvania	13a	600	RAIL	56½	1910	2	Pass	2B+B2	Jackshaft-Siderods	68	36	779	86	332	208	52.0	205	127	2130	45.1	17.7	156	1570	54.8	10.8	211	80	2	600	F	—	32-33	13a
			13b	600	RAIL	56½	1910	31	Pass	1B+B1	Jackshaft-Siderods	72	36	779	86	313	199	49.75	194	119	2150	41.8	16.7	147	1570	58.0	10.2	198	80	2	600	F	—	10-31, 34-41	13b
			13c	600	RAIL	56½	1910	1	Sw	B+B	Quill Gearless	56	—	465	102	185.1	185.1	46.79	100	95.14	630°	11.9	19.82	310	423	14.5	10.9	461	40	4	600	F	—	3951	13c
Total America								340								64101					644150														

Wheel Arrangement / Cab

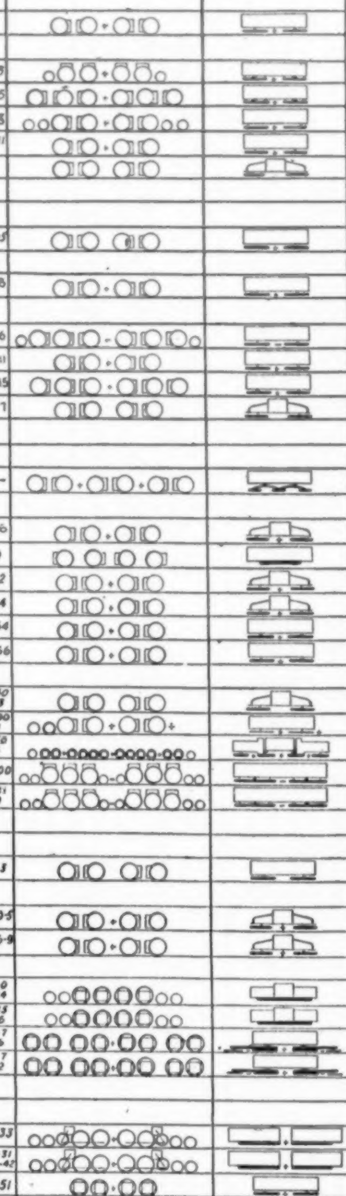


Table IV A. (Continued)

EUROPE	ENGLAND	NORTH-EASTERN	14a	1500	LINE	56½	1914	10	Fr't	B+B	Twin Gear	48	—	472	105	167	167	41.6	112.2	54.4	1100	20.5	18.6	13.2	635	22.8	10.4	263		4				14a
			14b	1500	LINE	56½	1922	1	Pass	2C2	Geared Quill	80	43½	642	192	228	124	41.3			1800	43.0	5.9	12.6	1300	51.5	94.8	175		3 Twin	750/1500	F		14b
	FRANCE	MIDI	15a	1500	BOTH	56½	1922	90	Pass	B+B	Twin Gears					158	158	39.5			1400			113	1000	46		158	55	4	1500	F		15a
			15b	1500	BOTH	56½	1922		Fr't	B+B	Twin Gear					158	158	39.5			1400			113	1000	24^{8}		158	40	4	1500	F		15b
			15c	1500	BOTH	56½	1922	2	Exp P	2C2	Vertical motors Geared Quills	69				224	119	39.6			2250			100					80.7	3 Twin	500			15c
		PARIS & ORLEANS	16a	600	BOTH	56½	1921	5	Pass	1D1	Side rod-yoke	59	34	480	192	192	150.6	36.4	104.8	87.4	2000	41.6		*96	1700			113	62	2	600			16a
			16b	1500	BOTH	56½	1922	80	F&P	B B	Gear	49		497	106	141	141	35.2			1400			100	1200			118		4	1500		21.65	16b
			16c	1500	BOTH	56½	1924	40	F&P	B B	Gear	53		512	110	141	141	35.2			1500			94	1200			118		4	1500			16c
			16d	1500	BOTH	56½	1924	80	F&P	B B	Gear	53		491	110	141	141	35.2			1720			82	1320			107		4	1500			16d
			16e	1500	BOTH	56½	1924	1	Exp.P	2C+C2	Gearless	47	36	744	112	238	159.6	26.6	138.6	102.9	2400	60	14.59	99.5	2100			113		6	750			16e
			16f	1500	BOTH	56½	1924	2	Exp P	2D2	Buchli gear	69				256					3800	39.2	35.8	67	3000			85		4	1500		2.57	16f
			16g	1500	BOTH	56½	1924	2	Exp P	2BB2	Crank siderod	69		618	73						3400				3000					4	1500			16g
		PARIS, LYONS & MEDITERRANEAN	17a	1500	BOTH	56½	~~1924~~	~~2~~	~~Exp P~~	~~2D2~~	~~Gear~~	63		825	106	264	158.4	39.6			2200			120						4 Twin	1500		3.88	17a
			17b	1500	BOTH	56½	1924	1	Exp P	2BB2	Walking beam side-rod	65		891	150	344	158.4	39.6			3000			114					-	2	1500			17b
			17c	1500	BOTH	56½	1924	1	Exp P	1C+C1	Gear	49		810	116	250	211.4	52.8			2000			125						6	750		2.44	17c
			17d	1500	BOTH	56½	1924	10	Fr't	1C+C1	Gear	49		810	116	250	211.4	52.8			2000			125						6	750		3.78	17d
			17e	1500	BOTH	56½	1924	10	Fr't	1C+C1	Gear	55		849	189	250	211.4	52.8			2200			113						6	750		4.35	17e
			17f	1500	BOTH	56½	1924	10	Fr't	1CC1	Gear	55		834	172	256	211.4	52.8			2000			128						6	750		4.45	17f
								— = Under Const'n.																										
	ITALY	ITALIAN STATE (MILAN-VARESE)	18a	600	RAIL	57	1923	5	P&F	1-C-1	Yoke Siderod	59	38	468	180	152	105.6	35.2	94.6	57.2	1360	54.6		112					59	2	600			18a
			18b	600	RAIL	57	1912	5	P&F	1-C-1	Jackshaft Siderod										1360									2	600			18b
	SPAIN	EL NORTE	19a	3000	LINE	56	1923	6	Fr't	C+C	Gear										1600	21.6	27.7		1550	21.8	26.7		37.2	6	1500		17.73	19a
			19b	3000	LINE	56	1923	6	Fr't	C+C	Gear	39.4		556	156	185	185	30.8	111	74	1620	22.0	27.5	114	1340	23.8	21.1	138	58.0	6	1500		18.61	19b
TOTAL EUROPE								369								59443					584020													
OTHER CONTINENTS	JAPAN	IMPERIAL GOVERMENT	20a	1500	LINE	42	1923	2	Fr't	B+B	Gear	55	—	492	112	130	130	33	70.5	58.5	1000	149	23^{5}	130					40	4	750	F	4.0	20a
			20b	1500	LINE	42	1923	2	Fr't	B B	Gear	42	—	446	102	132	132	33	82.4	49.6	1040	22^{5}	17.8	127	988	22^{8}	16.4	134	40	4	750	F	18.83	20b
			20c	1500	LINE	42	1923	2	Fr't	B B	Gear	49	—	487	109	121	121	30.2	78.78	42.17	1200	20.3	22.4	101	960	23^{9}	$15.^{6}$	126	40	4	750	F	16.72	20c
			20d	1500	LINE	42	1923	2	Fr't	B+B	Gear	49	—	490	111	132	132	33	75.5	43.5	1128	19.1	22.0	108					40.5	4	750	F	18.75	20d
			20e	1500	LINE	42	1924	17	Fr't	B+B	Gear	49	—	490	111	123	123	33			1224	21.1	21.8	108					43^{5}	4	750	F		20e
			20f	1500	LINE	42	1924	9	loc P	B+B	Gear	49	—	490	111	123	123	33			1224	28.0	16.4	108					58.4	4	750	F		20f
			20g	1500	LINE	42	1924	8	Exp P	1C+C1	Gear	55				214	161.2	26.8			1836	31.7	21.7	88					65^{9}	6	750	F		20g
	JAVA	NETHERLANDS EAST INDIES STATE	21a	1500	LINE	42	1924	1	Fr't	B+B			—			110					1200			92						4				21a
			21b	1500	LINE	42	1924	2	P&F	1B+B1	Gear	53	32½	504	98	110			66	44	1200	23.5	17.7	92	1050	29.0	12.6	105	45	4	750		18.70	21b
			21c	1500	LINE	42	1924	2	Exp P	1D1	Buchli gear	59				170					1500	34.2		114	1200	37.8			56	4				21c
			21d	1500	LINE	42	1924	1	Exp P	1B+B1	Siderod Jackshaft					170					1700			100					56	2				21d
	N ZEALAND	MIDLAND	22	1500	LINE	42	1924	5	P&F	B+B	Gear	45	—	428	105	107.4	107.4	26.8			680	18.0	14.2	138							750			22
	S. AFRICA	S. AFRICAN	23	3000	LINE	42	1924	78	P&F	B+B	Gear	48	—	492	111	146	146	36.5	84	62	1200	20.8	23.2	122	985	22.5	16.4	148	45	4	1500			23
TOTAL OTHER CONTINENTS								131								18719					160820													
		GRAND TOTAL						840								[illegible]					[illegible]													

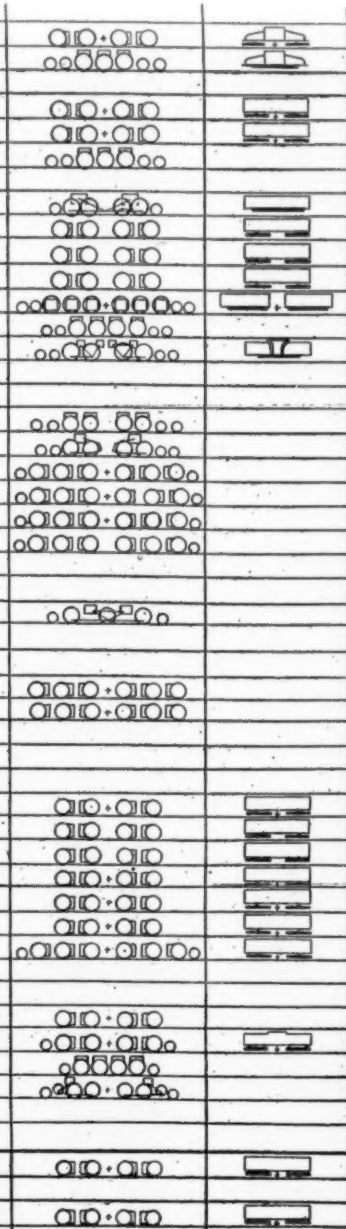


Table IV B. Alternating Current Locomotives

Continent	Country	Railway	Key No.	Contact Line Volts	Contact Line Freq	Gauge Inches	Year in Service	Number	Type of Service	Axle Classification	Method of Drive	Dimensions Inches: Wheel Diam. Driver	Wheel Diam. Idler	Length Overall	Rigid Wheel Base	Weights Thousands of Pounds: Total	On Drivers	Per Driving Axle	Mech Parts	Elect Parts	One Hour Rating: HP	MPH	TE Lbs/1000	Wt HP Lbs.	Continuous Rating: HP	MPH	TE Lbs/1000	Wt HP Lbs.	Max Safe Speed MPH	Motors: No.	Volts	Type	Gear Ratio	No of Transformers	Road No	Wheel Arrangement	Cab	Key No.
America	Canada	Grand Trunk	25	3300	25	56½	1908	6†	P&F	C	Gear	62		353	192	132	132	44	73.4	58.6	750	10.8	26.0	176	668	13.8	18.5	192	30	3		Series	6.85	1	1655 2660			25
	U.S. of America	Boston & Maine	26a	11000	25	56½	1911	5	P&F	1B-B1	Geared Quill	63	42	581	84	260	204	51	141.8	118.2	1500	24.4	23.0	173	1400	25.6	20.5	186	30	4	300	Series	22.91	1	4000 4004			26a
			26b	11000	25	56½	1917	2	P&F	1B-B1	Geared Quill	63	42	576	84	265.5	217	54.2	147.5	118	1510	24.2	23.5	176	1415	25.3	21.0	188	35	4	300	Series	22.91	1	4005 4006			26b
		Detroit & Ironton	27	11000 22000	25	56½	1924	2	Fr't	AC-CA	Twin Gear Flexible	42	—	702	132	340	340	42.5			2000	16.0	47.0	170	1750	17.0	40.0	194	35	8	600	Series D.C.	18.82	1				27
		New York New Haven & Hartford	28a	11000 600	25	56½	1907	41	Pass	1B-B1	Gearless Quill	62	33	450	96	220.1	169	42.3	108.1	112	1420	54.8	9.7	155	1125	66.0	6.4	195	88	4	220	Series	—	1	01-041			28a
			28b	11000	25	56½	1916	1	Sw.	2B-B2	Gear Siderod	84	33	744	120	291	194	48.8	172	119	1800	23.0	27.0	166	1600	26.4	22.2	187	45	4		Series	35.71	1	068			28b
			28c	11000 600	25	56½	1910	1	P&F	1D1	Gear Quill	63	36	560	132	234.4	174	43.0	114.1	120.1	1700	36.0	18.3	138	1380	41.0	12.6	174	54	4 Twin	275	Series	22.92	1	069			28c
			28d	11000	25	56½	1910	1	Sw.	1B-B1	Side-rod	57	36	644	96	270	192	48	138	132	1260	32.0	16.0	214	1044	35.6	12.0	258	61	2	510	Series	—	1	070			28d
			28e	11000 600	25	56½	1910	1	Pass	1B-B1	Gear Quill	63	42	476	84	288.9	186	46.4	160.3	128	1600	37.0	13.2	180	1160	48.0	11.8	249	58	4	500	Series	34.79	1	071			28e
			28f	11000 600	25	56½	1911	1	Pass	1B-B1	Gear Quill	63	36	476	84	256.4	193.8	47.8	128.6	128	1600	37.0	13.2	160	1160	48.0	11.8	222	55	4	500	Series	34.79	1	072			28f
			28g	11000 600	25	56½	1912-3	3	Pass	1B-B1	Gear Quill	63	36	600	96	248.1	189.8	47.4	133	115.1	1700	36.0	18.2	146	1350	41.6	12.4	184	54	4 Twin	275	Series	22.92	1	073 015			28g
			28h	11000	25	56½	1912-3	36	Fr't	1B-B1	Gear Quill	63	36	600	96	219.3	165	41.2	120.9	98.6	1700	25.1	24.0	129	1350	29.0	17.1	163	41.5	4 Twin	275	Series	17.97	1	076 0111			28h
			28i	11000	25	56½	1911	1	Sw.	B-B	Gear Quill	63	—	444	84	158	158	39.5	79.7	78.3	750	12.2	23.2	210	572	14.5	14.8	276	25	4	190	Series	17.101	1	0200			28i
			28j	11000	25	56½	1912	15	Sw.	B-B	Gear Quill	63	—	450	84	159.3	159.3	39.8	83.4	75.8	750	12.2	23.2	212	572	14.5	14.8	278	25	4	190	Series	17.101	1	0201 0215			28j
			28k	11000	25	56½	1919	5	Pass	1C1-1C1	Gear Quill	63	36	828	181	350	233	38.8	173.5	176.5	2550	46.4	21.0	137	2025	52.5	14.8	174	70	6 Twin	275	Series	27.87	1	0300 0304			28k
			28l	11000 600	25	56½	1923	12	Pass	1C1-1C1	Gear Quill	63	36	802	181	358	240	40.0	199.5	158.5	2510	48.5	19.3	143	2050	58.8	15.1	175	77	6 Twin	275	Series	25.85	1	0305 0316			28l
		Norfolk & Western	29a	11000	25	56½	1915	24†	Fr't	1B-B1	Gear Jackshaft Siderods	62	50	638	132	300	249	62.3	190	110	1600	14.5 28.6	42.0 21.5	187	1260 1450	14.3 28.6	33.0 19.0	207	35	2 Twin	725	3Φ Induc	16.85	1	2500 01-22			29a
			29b	11000	25	56½	1924	8†	Fr't	1D1	Flex Gear Jack Shaft Siderod	63	33	583	198	414	300	75.0	251.5	162.5	2030 2316	14.1 28.3	54.0 31.5	174	1700 2000	14.2 28.4	45.0 26.3	207	38	2	850	3Φ Induc	21.00	1	2512-9 12330			29b
		Pennsylvania	30a	11000	25	56½	1917	1	Fr't	1C-C1	Gear Jackshaft Siderods	72	36	918	160	516	439.5	133	258.4	257.6	4800	20.4	88.0	108	4000	20.5	73.0	129	35	4	850	3Φ Induc	21.106	1	3931			30a
			30b	11000	25	56½	1924	3	Fr't	1D1	Flex Gear-Jack Shaft-Siderods	80	33	819	261	408	300	75.0	225.1	182.9	3300	21.0	59.0	124	3070	23.0	50.0	133	35	4	350	Series	30.118	1				30b
		Virginian	31	11000	25	56½	1924-5	36†	Fr't	1D1	Flex Gear-Jack Shaft-Siderods	62	33	609	198	450	312	78.0	267	163	2030 2315	15.4 27.0	66.0 35.0	181	1700 2000	15.5 27.1	47.3 27.6	215	35	2	850	3Φ Induc	20.100	1				31
									† = Motive Power Unit																													
		— = Under Const'n.																																				
Total	America							205								58693					363550																	
	Austria	Mariazell	32	6600	25	30	1910-14	16	Fr't	C+C	Gear Jackshaft Siderod	31.3		434	94	104	104	17.3	53	51	592	21.7	10.2	175					31.0	2	220		3.0	2	1-14			32
		Mittenwald	33	15000	16⅔		1912-14	12	Fr't	1C	Jackshaft Siderod	40.7	34.2	405	157	117	92.1	30.9	64	53	789	18.7	15.9	148	492			238	28.0	1	810	Repul	—	1				33
		Vienna-Pressburg	34	16500			1914	6	P&F	1B1	Jackshaft Siderod	40.7	34.2	415	157	118	61.8	30.9	60	58	740	24.2	11.5	159	740	36.4	7.7	159	46.6	1	490	Ser Rep	—	1	EP1-8			34
		Austrian State	35a	15000	16⅔		1922	7	Fr't	1C-C1	Gear Jackshaft Siderod	53.1	34.2	775	152	250	192	32	151	99	2465	33.6	27.6	101					40.4	4	578	Series	3.22	1				35a
			35b	15000	16⅔		1923	21	P&F	1C1	Gear Jackshaft Siderod	66.9	39.1	504	223	157	96	32	73	84	1340	29.2 31.7	17.2 15.9	115					45.5 49.8	2	400	Series	4.21	1				35b
			35c	15000	16⅔		1923	20	Fr't	E	Gear	53.1		612	154	160	160	32	81.6	78.4	1450	24.9	21.8	110					31.1		385	Series	6.0	1				35c
		Baden State (Wiesenthal)	36a	15000	15	56½	1912	12	P&F	1C	Jackshaft Siderod	41.3	33.4	486	157	151.9	92.4	30.9	80.8	70.7	1035	28.0	10.2	146	769	49.1	6.6	197			300	Series	—	1	A³-1			36a
			36b	15000	15	56½	1913	2	Fr't	1C1	Jackshaft Siderod	58.2	39.0	470	142	154	95.0	31.9	86	68	798	34.2	9.5	192	640			241			1200	Repul	—	1	A²-1			36b
		Bavarian State	37a	15000	16⅔	56½	1914	5	P&F	1C2	Jackshaft Siderod	43.3	33.4	485			94.5	31.5	3	72.0	891	24.6	13.7	204		33.0	7.3		49.7	1		Series	—	1	EP3/6 20101-5			37a
			37b	15000	16⅔	56½	1916	5	Fr't	BB	Gear	45.3	—	433	98.7	123	123	30.8	70.0	53	788	18.6	15.0	156		18.6	7.5		31.1	4		Series		1	EG4 20201-5			37b
			37c	15000	16⅔	56½	1916	5	P&F	1C2	Jackshaft Siderod	45.3	33.4	528	102	207	106	35.3	119.0	88	1280	31.1	15.4	162		49.7	7.3		49.7	1		Series	—	1	EP3/6 20121-5			37c
			37d	15000	16⅔	56½	1913	5	Fr't	1C1	Jackshaft Siderod	41.3	33.4	478	187	152	92.6	30.9			986	18.6	19.8	154					31.1			Series	—	1	EP 2/4 002			37d
			37e	15000	16⅔	56½	1920	2	Fr't	B+B	Gear Jackshaft Scotch Yoke	49.2	—	490	108	134	134	33.7	76.8	57.6	886	18.6	17.0	150		18.6	15.2		31.1	2	415	Series	3.80	1	EG 20221			37e
		Unassigned	37f	15000	16⅔	56½	1924	10	Exp P	1D1	Buchli Gear	63	39.4	612		225	160	40.0			2360	39.0	22.7	95	1970	39.0	18.9	114	68	4		Series		1				37f
			37g	15000	16⅔	56½	1924	5	Exp P	2C2	Jackshaft Siderod	63	39.4	619		253	120	40.0			1450			174	1180			214	68	1°		Series	—	1				37g
			37h	15000	16⅔	56½	1924	35	Pass	2BB2	Gear Jackshaft Siderod	55.1	39.4	640		277	160	40.0			2270			122	1980			140	86	4		Series		1				37h
			37i	15000	16⅔	56½	1924	19	Pass	1C1	Gear Jackshaft Siderod	55.1	39.4	493		170	120	40.0			1180			144	986			172	44	2		Series		1				37i
			37j	15000	16⅔	56½	1924	37	Fr't	1B-B1	Gear-Jackshaft-Siderod	55.1	39.4	630		236	160	40.0			1890			125	1580			149	40	2		Series		1				37j
			38a	15000	16⅔	56½	1911	1	Pass	2B1	Jackshaft Siderod	63	39.4	493	118	162	72.4	36.2	102.5	59.5	1015	46.5	8.0	160	828	74.6	4.1	196	80.8	1	460	Series	—	1	ES-1			38a
			38b	15000	16⅔	56½	1911	1	Pass	2B1	Jackshaft Siderod	63	39.4	493	118	158	70.6	35.3	99	59	1180	49.1	9.0	134	591		4.7	267	80.8	1	870	Doubly Fed Series	—	1	ES-2			38b
			38c	15000	16⅔	56½	1912	1	Pass	2B1	Jackshaft Siderod	63	39.4	493	118	159	70.6	35.3	100	59	1480	49.7	9.8	107	1085	62.9	7.7	147	80.8	1		Series	—	1	ES-3			38c

Table IV B. (Continued)

EUROPE	GERMANY	PRUSSIAN STATE	38d	15000	16 2/3	56 1/2	1910	1	Fr't	1B+B1	Jackshaft Siderod	50	33.6	620		208	158.8	39.5	98	110	1580	24.9	17.6	132	1180			176	46.6	2	1235		–		16509-10	38d
			38e	15000	16 2/3	56 1/2	1912	1	Pass.	1C1	Jackshaft Siderod	49.2	39.4	510	154	179	110	36.7	89	90	1980	29.1	14.3	9.5	1180		8.4	152	68.4	1	525	Series	–	1	ES 6	38e
			38f	15000	16 2/3	56 1/2	1912	1	Pass	1C1	Jackshaft Siderod	63	39.4	515		187	114	38.0	97	90	1770	52.9	11.9	106	1480			126	68.4	1	525	Series	–	1	ES 5	38f
			38g	15000	16 2/3	56 1/2	1912	11	P&F	1C1	Jackshaft Siderod	53.1	39.4	488	184	185	112.6	37.5	101.5	84	1770	28.0	22.0	105	1230			150	68.4	1	640	Series	–		ES 9-19	38g
			38h	15000	16 2/3	56 1/2	1912	2	Fr't	D	Jackshaft Siderod	41.3	—	413	138	145	145	36.4	79.5	64.5	789	23.3	14.3	184	590			246	43.5	1			–	1	EG 502-3	38h
			38i	15000	16 2/3	56 1/2	191421	27	Fr't	B+B	Gear Jack Shaft Siderod	53.1	—	440	114	143	143	35.7	67	76	1180	22.2	19.8	121	986		15.9	145	31.1	2	510	Series	4.45	1	EG 511-37	38i
			38j	15000	16 2/3	56 1/2		7	Fr't	1C1	Jackshaft Siderod	49.2	39.4	510		183	112	37.4	102	81	1740	28.0	23.4	105	1180			185	56.0	1	640	Series	–		EP 202 B	38j
			38k	15000	16 2/3	56 1/2		13	Pass	2B+B1	Gear Jack shaft Siderod	66.9	2-39.4 1-45.3	650		254	154	38.6	143	111	2380	34.2	24.3	107					56.0	2	350	Series	2.79			38k
			38l	15000	16 2/3	56 1/2	191521	13	Fr't	B+B+B	Gear Jack-shaft Siderod	53.1	—	678	114	227	227	37.8	128	99					1150	18.7	23.2	198	31.1	3		Series	5.19		EG 538-50	38l
			38m	15000	16 2/3	56 1/2	1918	1	Pass.	2D1	Jackshaft Siderod	48.2	39.4	650		234	164	36.8	128	106	2960	31.5	32.6	79.0	2220	40.4	20.7	105	56.0	1	350	Series	–		EP 235	38m
			38n	15000	16 2/3	56 1/2	1921	10	Fr't	C+C	Gear Jack Shaft Siderod	49.2	—	628	169	212	212	35.3	119	99	1380			154	1220	20.1	23.2	114	31.1	4		Series	4.89		EG 551-2	38n
			38o	15000	16 2/3	56 1/2	1923	10	Fr't	C+C	Gear	49.2	—	662		218	218	36.3							1390	21.8		157	31.1	6		Series				38o
			38p	15000	16 2/3	56 1/2		1	Pass	1D1	Jackshaft Siderod	59	39.4	545		212	150	37.5			1183	46.0	8.8	179	788			270	68.4	2		Series	–		ES 4	38p
			38q	15000	16 2/3	56 1/2		1	Pass	1D1	Jackshaft Siderod	41.4	33.4	566	102	198.5	150	37.5			2560	43.5	18.0	78	1530	51.6	11.6	130	57.8	2	315	Series	–		EP 201	38q
			38r	15000	16 2/3	56 1/2		11		1D1	Jackshaft Siderod	49.2	39.4	518	156	222.5	154	38.5	137.6	85	2960	34.2	30.9	75					56.0	1	315	Series	–		EP 213-34	38r
			38s	15000	16 2/3	56 1/2		1		D	Jackshaft Siderod	41.4	—	414	138	137	137	33.2	78.4	58.6	591	18.6	11.9	232	493			278	37.3	1		Repul.	–		EG 504	38s
			38t	15000	16 2/3	56 1/2		1		D	Jackshaft Siderod	41.4	—	414	138	144.5	144.8	36.1	85.9	68.6	788	24.9	11.0	183	468	37.3	6.6	308	37.3	1	315	Series	–		EG 505	38t
			38u	15000	16 2/3	56 1/2		3		D	Jackshaft Siderod	41.4	—	394	144	141	141	35.2	70.5	70.6	1035	18.6	18.7	136	740			190	49.7	1	350	Series	–		EG 503-6	38u
		UNASSIGNED	37k	15000	16 2/3	56 1/2	1924	30	Fr't	C+C	Gear Jackshaft Siderod	49.0	—	660	—	242	242	40.4			2270			107	1970			123	34	2		Series		1		37k
	NORWAY & SWEDEN	DRAMMEN	39a	15000	15		1922	2		1B+B1	Gear Jack shaft - Scotch yoke	57.3	38.6	570	120	171	124	31.0	105	66	1180	20.6	21.6	145			16.2		31.1	2	520	Series	5.24	1		39a
			39b	15000	15		1922	22		BB	Gear Jack-shaft-Scotch yoke	57.3	—	502	118	137	137	34.3	85	52	927	20.8	16.8	147					37.3	2	358	Series	4.27	1		39b
		NORDMARK	40	15000	16 2/3	35	1920	15		1C1	Gear Jack shaft Siderod	38.4	27.6	367	138	86.6	55.9	18.4	48.8	39.8	428	15.5	99	207		15.5	73		37.3	1	500	Series	2.86	1		40
		GÖTEBORG	41	16500	16 2/3	56 1/2	1924	51		1C1	Gear Jack-Shaft Siderod	60.2	38.2	539	212	179	112.5	37.5			619			218					37.3	2			2.23 4.96			41
		RIKSGRANSEN	42a	15000	15	56 1/2	1914	19		1C+C1	Jack Shaft Siderod	43.3	28.7	733	169	305	232	38.7	172	133	1680	17.6	35.8	181			11.5			2	200	Series	–	2		42a
			42b	15000	15	56 1/2	1915	2		2B2	Jack Shaft Siderod	62.0	38.2	554	114	199	73.8	36.9	119	80	986	31.1	119	202						1		Series	–	1		42b
			42c	15000	15	56 1/2	1919	2		B+B	Gear Jackshaft Scotch Yoke	53.2	—	508	114	150	150.2	37.5	90.5	59.5	986	14.3	25.2	152		14.3	19.6			2	510	Series	4.45			42c
			42d	15000	15	56 1/2	1922	2		2B+B2	Gear Jackshaft Siderod	53.7	37.8	843	136	272	140	35.0	156	116	2230	41.0	20.3	122						4	295	Series	1.76	2		42d
			42e	15000	15	56 1/2	1922	10		D	Gear Jackshaft Siderod	53.2	—	443	136	151	151	37.8	93	58	1110	19.6	22.0	136					37.3	2	297	Series	2.82	1		42e
			42f	15000	15	56 1/2	1922	11		1C+C1	Gear Jackshaft Siderod	60.2	33.6	822	193	282	223	37.3	175	117	2860	24.2	42.0	102		28.0	30.0		37.3	2 Twin	365	Series	4.90	2		42f
	SWITZERLAND	LOETSCHBERG	43a	15000	16 2/3	56 1/2	1910	1		C+C	Gear Jackshaft Siderod	53.0	—	599	159	198.6	198.6	33.1	101	97.6	1970	26.0	28.2	101					43.4	2	420	Series	3.25	2	121	43a
			43b	15000	16 2/3	56 1/2	1914	13		1E1	Geared Jackshaft Scotch yoke	53.0	33.5	630	177	236	176.5	35.3	105.8	130.2	2465	31.0	29.7	96					46.5	2	520	Series	2.23	2	153	43b
			43c	15000	16 2/3	56 1/2	1920	14		1B+B1	Gear Jackshaft Scotch Yoke	53.0	33.5	566	114	151	112.5	28.1	87	64	1270	21.7	17.8	119	1035	21.7	14.6	14.6	46.5	2	400	Series	3.78	1	302	43c
		RHAETIAN	44a	11000	16 2/3	39.	1913	7		1B1	Jackshaft Siderod	42.0	28	340	102	80.6	48.0	24.0	41.6	39.	296	17.4	6.4	292					31.1	1	1000	Repul.	—	1	201-7	44a
			44b	11000	16 2/3	39	1913	1		1D1	Jackshaft Siderod	42.0	28	453	61	121.8	92.6	23.2	58.7	62.8	591	17.4	12.8	205	414			294	31.1	2	1000	Repul	—	1	301	44b
			44c	11000	16 2/3	39	1913	2		1D1	Gear Jackshaft Siderod Jackshaft	42.0	28	434	94	115	90.0	22.5	64	61	591	17.4	12.8	194	394			292	31.1	2	280	Series	4.48	1	351-2	44c
			44d	11000	16 2/3	39	1913	1		1D1	Gear Jackshaft Siderod Jackshaft	42.0	28	433	94	122	91.3	22.8	66.5	55.5	591	17.4	12.8						31.1	2	400	Series	2.65	1	391	44d
			44e	11000	16 2/3	39	1914	3		1D1	Gear Jackshaft Siderod Jackshaft	42.0	28	439	94	124	96.0	24.0	67	57	788	18.6	15.8	157					31.1	2	300	Series	4.15	1	3535	44e
			44f	11000	16 2/3	39	1918	1		1D1	Jackshaft Siderod	42.0	28	439	94	126	98.2	24.6	62.1	64.8	788	17.4	17.0	160	572			220	31.1	2	1000	Repul	—	1	302	44f
			44g	11000	16 2/3	39	19212	10		CC	Gear Jackshaft Siderod	42.0	—	524	129	145	145	24.1	83.7	61.3	1180	18.4	23.8	123					28.0	2	500	Series	4.13	1	401-10	44g
		SWISS FEDERAL	45a	15000	16 2/3	56 1/2	1919	20	P&F	1C1	Gear Jackshaft Scotch Yoke	53.0	36.5	530	185	200	129	43	103.3	96.8	1620	29.3	20.8	124	1330		16.1	150	46.5	2	500	Series	2.84	2	11201	45a
			45b	15000	16 2/3	56 1/2	1919	1	P&F	1B+B1	Gear Jackshaft Siderod	53.0	36.5	640	114	250	176	44	130	120	2260	33.5	25.3	111	1700	37.3	17.0	147	46.5	4	550	Series	3.47	1	11301	45b
			45c	15000	16 2/3	56 1/2	191923	41	P&F	1B+B1	Gear Jackshaft Siderod	53.0	36.5	640	130	235	168	42	127.5	107.6	1920	30.0	24.0	122	1700	37.3	17.0	138	46.5	4	630	Series	3.47	1	11302-42	45c
			45d	15000	16 2/3	56 1/2	1920	1	P&F	1C+C1	Gear Jackshaft Siderod	53.0	33.5	760	186	279	231	38.6	155.5	123.6	2010	21.8	37.5	139	1700	24.9	28.9	164	40.4	4	630	Series	3.24	1	14201	45d
			45e	15000	16 2/3	56 1/2	19202	33	P&F	1C+C1	Gear Jackshaft Siderod Scotch Yoke	53.0	36.5	760	186	282	238	39.7	161	121	2210	21.8	37.6	127	1680	21.8	28.9	168	40.4	4	500	Series	4.05	1	14251-82	45e
			45f	15000	16 2/3	56 1/2	1923-4	20	Pass.	2C1	Gear Jackshaft Scotch Yoke	63.5	36.5	850	186	209	125.8	41.9	119	90	1970	40.4	18.3	106	1580	43.5	13.7	132	65.8	2	400	Series	n	1	10401-21	45f
			45g	15000	16 2/3	56 1/2	1921-3	16	Pass.	2C1	Gear	63.5	36.5	580	186	202.5	125.8	41.9	109	93.8	2060	40.4	17.2	98	1715	40.4	18.0	118	65.8	3	550	Series	2.57	1	10301-17	45g
			45h	15000	16 2/3	56 1/2	19223	14	P&F	1C1	Gear	63.6	36.5	480	158	182	125.8	41.9	86	96	1770	38.6	17.2	102	1380	38.6	13.9	132	46.5	3 Twin		Series	5.20	1	5Z.	45h
			45i	15000	16 2/3	56 1/2	1921-3	6		1B+1B1	Gear	63.5	36.5	642	166	249	163	40.7	122.9	126.5	2360	33.5	26.4	105	1840		21.4		46.5	4 Twin		Series	5.72	1	5.Z.	45i
			45j	15000	16 2/3	56 1/2	1923	2	P&F	1C	Gear Jackshaft Siderod	41.0	33.5	398	160	108	89	29.7			590	17.6		183						2		Series	3.7	1		45j
TOTAL EUROPE								717								142377					111144															
GRAND TOTAL SINGLE PHASE								922								201009					1475094															

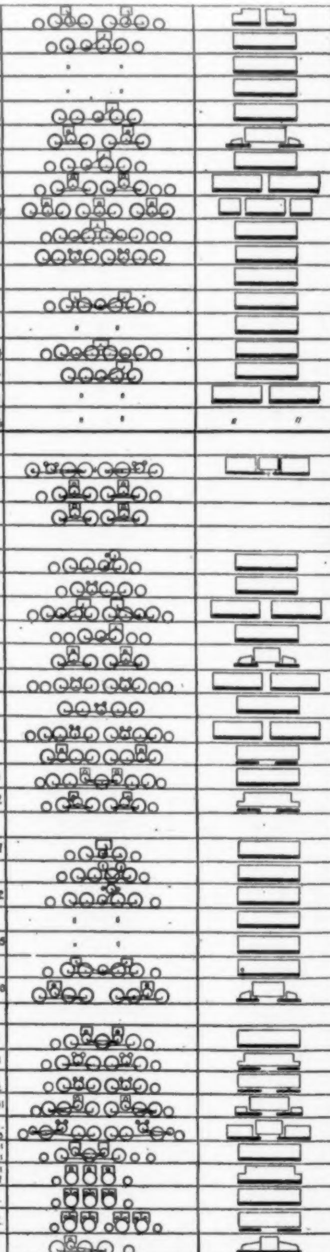


Table IV B. (Continued)

Continent	Country	Railway	Key No.	Contact Line Volts	Contact Line Freq.	Gauge Inches	Year in Service	Number	Type of Service	Axle Classification	Method of Drive	Wheel Diam. Driver	Wheel Diam. Idler	Length Overall	Rigid Wheel Base	Weights Total	On Drivers	Per Driving Axle	Mech Parts	Elec Parts	One Hour HP	One Hour TE lbs/1000	One Hour Wt HP Lbs	Continuous HP	Continuous TE lbs/1000	Continuous Wt HP Lbs	No. of Speeds	Synchronous Speed MPH	Max Safe Speed MPH	Motors No	Motors Volts	Ventilation	Gear Ratio	No of Transformers	Road Nos	Wheel Arrangement	Cab	Key No
America	U.S. of America	Great Northern	46	6600	25	56½	1909	4	P&F	B+B	Gear (Twin)	60	—	650	132	230	230	57.5	121	109	1500	38	153	1400	34.8	164	1	15.1	30	4	550		19:81	2	5000 [illegible]			46
Total	America							4								920					6000																	
Europe	Italy	Italian State	47a	3000	15	56½	1902	2	Fr't	B+B	Gearless	85	—	405		101.4	101.4	25.4	46.5	55.5	895	18.8	114	890	12.8	172	1	18.6		4	3000		—	—	Gr 34			47a
			47b	3000	15	56½	1903	3	Fr't	1C1	Scotch Yoke	59	33	448		136.5	92.4	30.9	66.5	70.6	1184	11.8	115				2	30.8		2	3000		—	—	Gr 36			47b
			47c	3000	15	56½	1906	4	Fr't	1C1	Scotch Yoke	59	33	445		136.5	92.0	30.9	70.6	66.5	1480	14.3	92				3	30.8		2	3000		—	—	Gr 38			47c
			47d	3000	15	56½	1909	180	Fr't	E	Scotch Yoke	42	—	374	151	132.5		26.6	66.5	66.5	1913	23.9	67				4	31.0		2	3000		—	—	E 550			47d
			47e	3000	15	56½	1915	16	Pass	1C1	Scotch Yoke	64.1	35.4	423		161	105.9	35.3	72.7	88.3	2642	21.8	61				4	46.6	62.1	2	3000		—	—	E 330			47e
			47f	3000	15	56½	1917	6		2C2	Jackshafts Siderods	64.1	37.8	525	138	202.8	119.1	39.7	107.8	95.	2604	21.0	78				4	46.6	62.1	2	3000		—	—	E 332			47f
			47g	3000	15	56½	1918	18		2C2	Jackshafts Siderods	64.1	37.8	588	138	202.8	110.5	36.8	110.1	92.7	2604	21.0	78				2	46.6	62.1	2	3000		—	—	E 331			47g
			47h	10000	45	56½	1923	8		1D1	Gear Jackshaft Scotch Yoke	64.1		571		200.6	141.2	35.3			2662	21.4	75				4	46.6		2			2.7					47h
			47i	10000	45	56½	1923	10		E	Gear Jackshaft Scotch Yoke	42	—	314	251	167.7	167.7	33.5			2268	27.4	74				2	31.0		2			3.625					47i
			47j	10000	45	56½	1924	10		1D1	Gear Jackshaft Scotch Yoke					196			79.1	117.9	5250	31.9	37					20.7-31 41.5-62	62	2								47j
			47k	3600	16⅔	56½	1924	150	Fr't	E	Scotch Yoke		—			158.5	158.5	31.7			2680	33.0	59				2	15.6 31.0		2	3600		—	—	551			47k
			47l	3600	16⅔	56½	1922	15	Fr't	E	Scotch Yoke		—			158.5	158.5	31.7			2680	33.0	59				4	[illegible] 21-31		2	3600		—	—	552			47l
			47m	3600	16⅔	56½	1924	30	Pass	1D1	Scotch Yoke					202.5	132.0	33			2680	20.9	76				4	15-31 46.9-62		2	3600		—	—	431			47m
		— Under Constr'n	47n	3600	16⅔	56½	1923	40	Pass	1D1	Scotch Yoke					165	105.0	35.		93.8	2680	26.4	62				4	15-23 31-46		2	3600		—	—	333			47n
	Switzerland	Simplon Tunnel	48a	3000	15	56½	1907	3	P&F	1C1	Scotch Yoke	64	33.5	485	195	138	100	33.3	74	64	1085	9.6	127		8.9		2	42.3		2	3000		—	—	364			48a
			48b	3000	15	56½	1909	2	P&F	D	Scotch Yoke	49	—	489	87	182	182	38	74	78	1677	14.6	91				4	42.8		2	3000		—		367			48b
			48c	3000	15	56½	1915	1	P&F	1D1	Oblique Side rod-Jackshaft	49	33.5	492	85	158	153	38.3	98	97	2760	23.6	71				2	44.1	46.7	2	3000		—	—	371			48c
Total	Europe							498								7749.3					[illegible]																	
Grand Total	Three Phase							502								7841.0					131390																	

is a material factor in determining the size and weight of motor selected.

The alternating current series motor characteristic is somewhat steeper than that of the direct current series motor. Inasmuch as the use of alternating current in a motor is always accompanied by induced currents due to transformer action, this, in a series commutator motor, affects the conditions under the brushes which determine their action, thus restricting within definite limits the torque output per motor pole (particularly at or near standstill), and this, where needed for slow or frequent heavy starting, will result in a heavier motor weight and cost than for direct current motors at the lower voltages for the same service, especially with the smaller capacities of individual motors. The voltage of the a.c. motors is low, their stability high, and they may be run on ungrounded circuits so that under proper conditions their operation is comparable to direct current motors. The condition of current supply is a factor of less importance owing to the transformer which is interposed between contact wire and motors. Control of speed is easily accomplished and is relatively simple and efficiently secured by the use of taps from the transformer without changing motor grouping or the use of external resistance.

The three phase induction motor, used also with phase converter, is practically a constant speed motor and has characteristics very different from the two described above. Additional speeds are obtainable through varying (by connection) the number of poles or by cascade connections between motors, but in general for freight service for which this type has many advantages, it is seldom necessary to have more than two speeds. Acceleration is accomplished by varying the external resistance inserted in the motor secondaries. Very high starting torques are obtainable with this type of motor, as well as capacity to carry heavy loads. As constant speed is maintained irrespective of the load, the horsepower input will vary almost directly with the tractive effort. As no commutators are used this is the simplest form of electric motor and the questions of commutation and stability do not have to be considered.

All three types lend themselves to regeneration. The induction motor is inherently the best by far as it automatically, without additional apparatus for switching, separate excitation or regulation of any kind, becomes a generator, whenever the locomotive while descending a grade exceeds the synchronous speed. No question of stability, flashing or expert manipulation enters into the matter at all.

Both the direct current series motor and the alternating current series motor have been successfully used for regeneration although considerable aditional apparatus or the use of certain of the main motors in order to obtain separate excitation when regenerating, is necessary.

The D.C. series motor, if furnished a local supply of direct current from a motor generator set on a single phase locomotive secures the utmost in favorable conditions for the operation of a direct current series motor. The motor may be designed to secure the maximum obtainable economy of weight and space and also the most appropriate voltage across commutator and winding can be used. Furthermore, the motors may be operated on an ungrounded circuit. This simplifies the insulation and creepage problem and insures better commutation and stability although the need for this is materially less, due to both the motor generator and the transformer being interposed between the motors and the contact system. Due to the wide range of speed control, higher horsepower can be maintained at higher speeds, and due to the control of generator voltage a most simple control system for both motoring and regeneration is secured. By the use of a synchronous motor on the motor generator set most favorable conditions of power factor can be realized. Rheostatic losses on this type of locomotive are practically eliminated. Furthermore, the resulting economy in size and weight of both motors and control considerably offsets the additional weight of motor generator set required.

Figure I shows the typical characteristics of the direct current series, the alternating current series and the alternating current induction motors, and the direct-current series motor used with locomotive motor generator set, as well as that for the steam locomotive.

In general, then, it can be said that the direct current series motor for a given weight has certain outstanding advantages for certain applications owing to its torque speed characteristics. As to speed control and as a generator it has certain disadvantages, all of which by additional apparatus and design can and have been successfully met. If used with a motor generator set on the locomotive its limitations are very greatly reduced. It lends itself particularly to subdivided power on account of its size-and-weight-efficiency and ease of grouping which is required to overcome its speed control limitations. The individual drive therefore will be found best adapted for this type of motor. This can be the gearless direct drive, geared, axle hung (the street railway type), frame mounted with quill, (geared or gearless) or with universal rod and pin drive.

With the greater space requirements needed by a single phase series motor its use as direct gearless and for axle hung mounting is restricted to the relatively smaller sizes, while for frame mounting with gared quill or universal drive space limitations do not usually

govern. The necessity for laminated structure, distributed windings and more brushes, together with the relatively lighter frame sections, adapts this type of motor in the largest sizes to frame mounting with collective drive (with or without gears) by which one motor drives more than one driving axle.

The induction motor is adapted particularly for heavy service where constant speed is desirable, for reasons of simplicity of control and for the attainment of the highest weight efficiency with large motors. These make the collective drive the desirable one for this type of motor.

Types and Classification of Drive

Drives can be definitely classified as individual and collective. The individual drive lends itself particularly to both the direct and the alternating current series motors, excepting the later when very heavy tractive efforts are involved, or when high motor weight efficiency or light axle loadings are the requisites. Collective drives lend themselves particularly well to such conditions and also to the best conditions for the use of the induction motor.

The continental engineers have apparently favored the collective drive for the alternating current series motor even in cases where the individual drive might have been used.

For the further description, advantages and limitations presented by the various drives, reference is made to Table III.

(a) The single reduction geared, nose and axle suspended motor with single or twin gears has been the logical development from the early street car motor. It advantages are due to its extensive use, its simplicity and relative cost. It is most effective for slow speed freight locomotives and when the individual motor rating or relative tractive effort is not too great. Its disadvantages are the restriction to armature length and diameter, the relatively high-non-spring-borne-weight on the axle (the effect of which is neutralized somewhat by the spring nose suspension and the use of spring gears), and to its relative exposure and inaccessability. Its limitations are greater where twin gears are used due to the greater restriction in length between wheel hubs.

(b) The advantage of the direct drive with armature mounted upon the axle is the directness by which transfer of torque to the wheels is acomplished with the entire elimination of drive mechanism and all losses connected therewith. The elimination of driving losses is to a material extent offset by the high copper losses of the field due to the large number of turns required by the large air gap and to the high copper losses of armature due to the considerable percentage of relatively inactive windings. The slow motor speed results in a low weight efficiency of motor and the proximity of motor to the roadbed imposes certain difficulties from exposure. The use of this type is necessarily confined to relatively high speed passenger service owing to the limited torque capacity.

(c) The direct quill drive has the advantage that it permits the use of a motor whose armature as well as its field frame is completely spring supported. It further permits relative economy in design and use of windings and secures a normal design of low speed motor. It has however, the common disadvantage of low speed and relatively low weight efficiency of the motor and is further subject to certain inaccessability of the spring drive elements and to proximity to the roadbed. This type is likewise limited to high speed service on acount of its limited torque capacity.

(d) The geared quill drive secures completely spring borne frame mounting of the motors, the elevation of the motors from the roadbed, and their better placement as to overall weight distribution of the locomotive (notably that of height of center of gravity). The motors are less exposed and opportunity is afforded for twin motor mounting which secures certain advantages, notably those of simplified gearing, less space restrictions, reduction in voltage across commutators and better opportunity for motor groupings when required for speed control.

The disadvantages are mainly those due to the maintenance and replacement of the springs or of the elements of the drive which are subject to relative motion. These objections have more or less importance depending on the torque transmitted and on the relative vertical displacement of axles to locomotive frame which is governed both by number of axles and conditions of track surface. There may be some further objection due to the spring connections acting in parrallel with the equalization system.

The quill geared drive is in successful use with both d. c. and a.c. series motors, both for high and low speed for all classes of passenger service, and for medium heavy freight and switching locomotives in this country and for all services with a.c. series motors.

(e) With frame mounting and individual universal rod and pin connection from gears to drivers the same advantages of placement obtain as with the geared quill drive with the substitution of mechanism for the springs which overcomes objection to spring drive maintenance and possible weight transfer at the expense of somewhat increased complication. This type of drive has distinct promise for services where individual drives are permissable.

(f) The direct side rod drive. This was the result of the natural attempt to get away from the limitations of the street railway type motor and to follow the design of the steam locomotive in order to retain certain of its favorable characteristics such as high center of gravity, favorable wheel spacing, etc. It has been used experimentally on several locomotives usually with direct connected oblique main rods. Under certain dynamic conditions, excessive stresses in rods or pins are developed. This design has not been duplicated to any great extent for succeeding locomotives, and, where used, two oblique rods and two motors are usually employed.

(g) The direct side drive with scotch yoke was first generally used by von Kando on the three phase locomotives designed by him for the Italian Railways. The scotch yoke has the advantage of permitting vertical movement between motors and drivers and also admits of motor mounting somewhat above the center line of drivers. This drive is well adapted for the direct connection to large slow speed motors and is in extensive use on a large number of Italian locomotives. The same principle of sliding rod bushing has been used in various adaptions of side rod drive for single phase locomotives.

(h) Jack shaft rod drive. This drive was the logical development of the direct side rod drive. By its use certain stresses due to the static and dynamic characteristics of the general type of drive were better taken care of. It is limited to the higher speed locomotives on account of the low weight efficiency of the motors at the lower speeds. It has found a limited number of applications both with d. c. and a. c. motors. A notable example of its successful use is the 33 d. c. locomotives of the Pennsylvania Railroad at their New York Terminal. It is at present, to a very limited extent, being duplicated for certain services by certain continental railways, a flexible element, however, being interposed at the armature.

(i) Geared jack shaft drive. This is a modification of the direct jack shaft drive through the employment of gears which admits the use of higher speeds and lighter motors and main rod with minimum angularity relative to the side rods. The use of flexible gears secures the advantageous cushioning of drive. The incorporation of these various features has practically eliminated the major troubles incident to the side rod drive under certain conditions. It is now in successful operation in all classes of service. Instead of the simple main rod, in certain applications, the scotch yoke or its principle has been used.

The common disadvantage of all drive connections between the rotating masses of the motors and those of the wheels is due to changes in angular velocity between the two, each having its own inertia. Rod drives are in particular more susceptible to this, owing to the inclusion of more driven wheels, larger motors, and more elements with clearance, together with transfer of load from one side to the other due to the use of crank motion. The difference in these respects from those obtaining with steam locomotives lies in the broad fundamental kinematic difference between the two—the electric drive is a mechanically closed system while the steam drive, on the other hand, is an open system. Experience has shown this to be a vital difference and one which must be provided for in order to satisfactorily take care of all conditions and speeds. These provisions are effected either by designing the drive and mechanical parts involved strong enough to withstand the high stresses imposed under certain conditions (either with or without flexible elements); or, on the other hand, a lighter design (preferably with flexible elements) with provision for close clearances and their rigid maintenance.

Locomotive Assembly

In wheel and axle arrangement, access to and mounting of motors, access to and mounting of control, and current collecting and auxiliary equipment, the locomotive assemblies may differ widely.

Motors and Drive

The various forms of motor and drive have been discussed in more or less detail by reason of their being essentially major elements.

Running Gear

It will be noted from Table IV that running gears bear different relationships to each other and to the cab or frame structures. The simplest form is the independent-cab and four wheel swivel truck with tractive effort transmitted through cab underframing and center pins, used for locomotives with the lesser tractive efforts.

For the larger locomotives the running gear may comprise a single wheel base alone or several connected by hinges, or by coupling either with or without buffers. For the slower speed locomotives auxiliary trucks are often not needed but where operation is required over a considerable amount of critical curvature, guiding is improved by the use of hinge connection. For the heavier and higher speed locomotives auxiliary trucks are employed; these are of varied types, both two-wheel and four-wheel. They serve various functions such as carrying weight, easing track stresses, providing stability on tangents at high speeds, and guiding on curves. The last two may be supplemented by hinge or special connections which utilize the friction forces of the drivers or the lateral component due to tractive effort to secure guiding or dampening.

The general practice in America follows the steam practice of supplying restraint to trucks by the use of heart links or rockers,

without provision for special driver axle play. The usual continental practice, on the other hand, is to employ spring or inclined plane, or combined motion with adjacent driver. Long rigid wheel bases are commonly employed even with high curvature by the provision of ample lateral play of the driving axles involved and of their driving rods.

The two-way operation of electric locomotives having restraint elements in auxiliary trucks imposes greater difficulties in securing favorable guiding on heavy curvature than is the case with steam locomotives with one-way operation. This may be overcome or eliminated by adequate attention to design. Owing to the great variations in the design of auxiliary trucks and difficulty of classification these have not been indicated in Table IV.

Wheel Arrangement

The wheel arrangements or configurations of running gear in Table IV can be readily recognized from the diagrams. The continental classification was used as it simplified compilation of data and as the diagrams fully describe. The adaptibility of the various drives to various wheels spacings and arrangements will be readily apparent from the table.

Axel Loading

Practice as to permissible axle loading in America differs widely and has not been definitely established. Steam locomotive axle loadings have progressively and universally increased, likewise those of the electric locomotives until on some of the notable recent locomotives the loading reaches approximately 80,000 pounds per driving axle. However, owing to the complete counterbalance for all speeds, obtainable on electric locomotives (due to the absence of reciprocating parts) this loading is considered to be less severe on structures and permanent way than a steam locomotive, even with its lesser static loading, because the latter has a periodic increment due to dynamic augment occasioned by imperfect balance of reciprocating parts. For conditions of high speed or heavy axle loading, due provision can be and usually is made to minimize the non-spring-borne weight, and also to secure the most favorable wheel spacing for minimizing track stresses.

Auxiliary Apparatus and Cab

For the control of the motors and various other purposes, switches and other apparatus and equipment are required. There are two general types of mounting; one, with a self-contained cab, mounted on two or more trucks or running gears, and carrying and housing the auxiliary apparatus; the other, with the cab structure borne by and integral with each running gear. The first type having relative movement requires a much heavier cab structure with special supports, and also flexible connections for the electrical circuits, air sand and oil lines, and forced ventilation system. In the case of the integral cab these flexible connections are not required. Owing to the absence of relative movement between motors and control apparatus it becomes possible to mount control and ventilating equipment directly upon the motors and all other equipment may be mounted directly upon the locomotive frame. The cab structure thus becomes merely a housing for the protection of the operators and apparatus. As will be noted from Table IV combinations of both are sometimes used.

Miscellaneous

The various other elements of an electric locomotive which have a material influence upon the design of running gear and cab structure, such as equalization, spring systems, current collecting devices and braking arrangement and equipment, could not well be included within the scope of this paper.

Conclusion

While the steam locomotive is a self-contained entity in most of its details of design and of its operation, it is seen that the electric locomotive, on the other hand, is dependent on and controlled, both as to design and possible limits of operation, by the other necessary component elements of a Railroad Electrification. Conclusions on electric locomotives are consequently a compromise to realize the overall objective, therefore discrimination is necessary when comparisons of electrifications are based solely on locomotive design, costs or performance. Review of the tables herein will show the history and trend of locomotive development as to systems, types and countries. While both the applications and the services differ, so do the objectives—whether they be, for instance, fuel savings or future service conditions.

Transportation, so largely the yardstick of civilization, must and will be improved everywhere. Where the advance is the greater, there will the greater achievements result. The design and perfection of the electric locomotive, it will be noted, are being given intensive consideration universally, although here in America railroad development of recent years has been relatively slow. The present notable activity of our heaviest carriers—The Pennsylvania, the Norfolk & Western and the Virginian Railway—and of Henry Ford for the Detroit and Ironton on electric locomotive design and application, assures a continuation of development for the future requirements of our American railroads.

Discussion

J. A. Carmody (N. Y. C.): Mr. Shepard has made a very able presentation, in a clear and concise manner, of facts concerning the types and development of the electric locomotive. The paper states that there are in service, or under construction, approximately 140 low voltage direct current locomotives in all countries, or 128 in the United States. Of these, the New York Central operates 73, or over 50 per cent. These 73 locomotives are divided into two distinct types as regards wheel and underframe arrangement, all of which employ bi-polar gearless motors. The service performed by these locomotives to date has been phenomenal, as is made evident by the fact that only now, after 17 years of heavy passenger and passenger switching service, the original 35 "S" locomotives are about to be shopped for heavy repairs or general overhauling.

These engines, which weigh 110 tons each, have been engaged in the severest kind of service between Grand Central Terminal and the car storage yard at Mott Haven, a distance of about six miles. During the 17 years of service, these 35 locomotives have made an average of nearly 450,000 miles each, or approximately 2,200 miles per locomotive per month. The average cost for maintaining these 35 locomotives, including inspection, repairs, renewals and painting, has been about 6 cents per locomotive mile. During the first nine years the average cost was about 3.5 cents per locomotive mile. Since 1916, however, the cost has increased to a maximum average of 18 cents per locomotive mile in 1923. This increase has been due partly to the ageing of the locomotives and partly to the increased cost of labor and materials, which have more than doubled during this period. It is estimated that the cost of the general overhauling will be approximately $12,000 per locomotive, and that when the work has been completed the locomotives will be practically as good as new and the probable life possibly doubled.

The performance of the 12 later locomotives, built in 1908, which are a modification of the original, and the 26 "T" locomotives, has been equally gratifying, and while they are not yet due for overhauling, it is expected that their probable life will be equally as great, if not greater, than that of the original locomotives.

W. L. Bean (N. Y. N. H. & H.): As an engineering proposition, electric locomotive design, as in the automobile, has developed to its present high state far more rapidly, more intensively and more confidently than has been the case with the steam locomotive. One characteristic of the steam locomotive is the difficulty in always having all parts of the machine functioning with such equality of efficiency as to produce a total harmonious and efficient result.

A steam locomotive under test conditions may give superior results, but under ordinary conditions of maintenance and handling will fall short because of improper steam distribution, poor packing, boiler troubles or what not, whereas with the electric locomotive the energy output-input ratio is nearly constant throughout the period of use from one overhauling to another.

Another inherent advantage in favor of the electric locomotive is that the human factor as represented by the handling of the engine by the crew is of much less importance from the standpoint of engine capacity and efficient use of energy. In steam locomotive operation, on the other hand, there are largely variable human factors such as efficient or inefficient firing, handling of water,

cut-off and throttle opening, which affect the extent and efficiency of power output.

One peculiarity inherent in electric versus steam locomotives is that the former may be likened in characteristics, in a sense, to a spirited horse which will exert itself to the extent of injuring itself in trying to handle loading beyond its normal rating, whereas a steam locomotive is, so to speak, of the temperament of a mule and will stall under overload. Operating men not usually being technically informed on the subject, often have difficulty understanding that overloading an electric engine for several trips may and often does cause premature breaking down of insulation, resulting in an unexpected motor failure with considerable damage to electrical appliances. Keeping the gear ratio such that slippage of wheels occurs before damaging currents develop in motor circuits will assist in controlling this trouble.

The N. Y., N. H. & H. has one or more electric locomotives of the types which permit of a high center of gravity, simplify gearing problems and do not involve difficulties incident to the use of side rods in the transmission of power from the motors to the wheels and in the maintenance of the locomotives.

The first considerable group of the N. Y., N. H. & H. locomotives, 40 in number, contains some members about 17 years of age. It is interesting from the standpoint of comparison with steam that those engines have made approximately a million and a half miles in services. Now after such mileage in steam, assuming 30,000 miles as an average for steam locomotive equipment per year, the age of the steam locomotive would be 50 years. The steam locomotive, when 30, 35 or 40 years old, would at least be retired to branch or secondary service whereas these electric locomotives are operating out of the Grand Central terminal on heavy express trains.

At present, the motor-generator set locomotive is attracting considerable attention. This is the type Henry Ford is reported to be developing. In addition to the use of this type on an electrified railroad with an overhead contact system, the same locomotive, with an internal combustion engine, can be used on branches of the railroad not in the electrified zone. By the use of standard motors and generators, a universal motor-generator electric locomotive may possibly be evolved, differing fundamentally on various roads only in the motor of the motor-generator set. This would help electrification considerably, in that it would be a big step toward quantity production.

The electric locomotive may have to compete with the internal combustion locomotive and the steam turbine locomotive. The above types have used, experimentally, electric as well as mechanical transmission.

Probably the greatest interest in the electric locomotive, except for those face to face with the details of equipment for a specific electrification problem, lies in the broad considerations of comparisons between costs and train operation results. Detailed comparisons of costs, whether between electric and steam, or between electric in one application and electric in another, altogether depend on the usually complicated conditions or different problems, involving masses of details difficult and often impossible to integrate or weigh. Therefore, generalizations as to the financial economies of using steam or electric locomotives are of little value.

Except for exceptional and relatively unimportant applications of heavy electric traction, it may, however, be stated broadly that the electric locomotive cannot compete on a financial basis, except where there is heavy density of traffic, or low hydro-electric power costs in a territory where fuel is of high price.

A certain design of electric locomotive costs 2.15 times as much as a modern steam engine of equivalent capacity. A multiple-unit motor car of certain design costs 20 per cent. more than a modern heavy Pacific steam engine and will only handle itself and two trailers.

All comparison of costs of steam versus electric motive power, both on maintenance and operating bases, must not, if it is consistent, overlook the important essential fact that the steam engine is a fully equipped, self-contained unit, whereas the electric locomotive in itself compares only to the machinery, and running gear of the steam locomotive; in other words, the steam engine minus tender and boiler.

Sometimes there is not proper consideration of these factors, as when there is direct, simple comparison of electric locomotive repair costs per mile per unit with steam on the same basis. One must include maintenance of power plant and of transmission and of distribution lines, as part of electric locomotive costs. The same is necessary in comparing engine failures, etc. Strictly speaking a power plant failure or a transmission system break-down is an engine failure.

As pointed out by the report of the Committee on Electric Rolling Stock, the fixed investment per unit of equipment capacity is heavy because of high prices for electric locomotives, and because of having to include power stations and distribution lines. This has an important bearing in relation to varying volumes of railway traffic in that when it is necessary, so to speak, "white lead" electric locomotives, much more capital becomes idle than with steam equipment. Therefore, traffic must not only be dense but uniform in order that the electric locomotive can develop the greatest economies.

(The meeting then adjourned).

Yesterday's Entertainment

The daytime features provided by the Entertainment Committee on Friday, consisted of the customary morning concert at 10.30 a.m., in the Entrance Hall of the pier, orchestral concert and impromptu dancing at 3:30 p.m., followed by tea at 4:30 p.m.

The evening program was designed to be especially appropriate to Canadian night, in honor of the many attendants whose homes are across the border. To the usual informal dancing some special features were added the chief of which was a song dedicated to "Jim Coleman," of the Canadian National Railways, Chairman of Division V, Mechanical, 1922-1923, and rendered by a miscellaneous bunch selected from among his host of friends, to the tune, "Blue Bells of Scotland." The words follow:

1. Old King Cole was a good old soul, in the days of the fiddler's three,
But our "Big Jim," put it all over him, in the days of the M. C. B.

Chorus
Jim Coleman is a man of his word, known near and far,
He's led the way for forty years on the good old C.N.R.

2. Our Big Jim for twenty-three years has made us toe the line,
With "Recommended practice" and with "standardizing fine."

Chorus
A regular man is our "Jim," he's put us where we are;
First the M. C. B., then the A. R. A., now the good old C. N. R.

3. The A. R. A. is here to stay, and if our dreams come true,
We will still have Jim with us, for a cen-tu-ry or two.

Chorus
We'll give three cheers for him,
He's our guiding Star, we say;
We will stand like hell for Jim as well, as the good old A. R. A.

A second special feature of the evening's entertainment was given by a Scottish troupe, the Sutcliff Family, in classic selections of songs, interspersed with and accompanied by dancing of Scottish dances.

The program of this evening was as a whole one of the most attractive of the convention season and for its conception and careful working out, great credit is due to the Entertainment Committee, C. W. Floyd Coffin, chairman, and the sub-committeee in direct charge, Webb G. Krauser, chairman, J. A. Cameron, vice-chairman, in place of J. W. Coleman, who was not able to be present; J. Cizek, W. L. Enbank, Langley Ingraham, H. A. Matthews, H. A. Pastre and Lewis B. Rhoades.

Dont's for Master Mechanics (and Others)

H. M. CURRY, who retired as general mechanical superintendent of the Northern Pacific last November after 43 years continuous service with that system, has been enjoying good health and has been keeping up contact with his wide circle of friends by attendance at railway conventions. His son, Ezra B., a graduate of the University of Minnesota, is welding supervisor of the Chicago, Milwaukee & St. Paul, with office at Minneapolis, Minn. Both father and son will be at Atlantic City.

Mr. Curry, a number of years ago, was inspired to draw up some "don'ts, orginated as a memory refresher or reminder for the special consideration of some division master mechanics." As a matter of fact they apply with equal force to all men in supervisory positions. They are well worth careful study.

1. Don't recommend or authorize any increase in force in either locomotive or car department unless after careful personal investigation it is found necessary to maintain a proper standard of service and equipment conditions.

2. Don't retain in the service at an expense to the railway company a single employee whose services are not an absolute necessity.

3. Don't allow your subordinate officers to think for a moment that you will not hold them strictly to account for retaining any supernumeries around their plants, or a larger fore than actually required.

4. Don't spend any of the company's money without knowing that such expenditure is necessary, right and proper.

5. Don't allow any of your subordinate officers or employees to gain the impression that you will tolerate dishonest or disloyal acts.

6. Don't overlook the fact that a railway officer's reputation is largely established by the correctness of his judgment. It should, therefore, not be hastily made or submitted, it being wise in cases of importance to adopt the old adage of "sleeping over it," sometimes one night, sometimes more than that. One's best thought is early in the morning, and deductions made and conclusions arrived at at that time are usually the best. In short, adopt Davey Crokett's adage: "Be sure you're right, then go ahead."

7. Don't sign a single requisition for tools or material of any description unless you know they are actually needed to meet service demands, or that an economy will result if furnished; and be sure in making special requisitions to give definite reasons for originating them and the furnishing of tools and material designated.

8. Don't forget, or let any of your staff do so, that the successful master mechanic and staff are those who maintain satisfactory conditions at low cost figures, and have locomotives and cars run free from failure and render economical service.

9. *Don't ever transact business with,* or issue instructions to employees direct who are working under officers subordinate to you.

10. Don't imagine that you are saving the railway company money by resorting to sharp practices in dealing with any class of employees as regards application of rates and working condition agreements; such practices always are individually and collectively resented and the invariable result is undesirable agitation and increased expense to the railway company.

11. Don't overlook the importance of so transacting business and treating employees that an *esprit de corps* is created and continuously maintained. It establishes a mutually wholesome confidence that means many dollars and cents saving to the railway company in securing better service than would otherwise be possible.

12. Don't forget that keeping your power and equipment, also the company's premises, in a decent and wholesome appearing condition is not an unnecessary expense, but instead a real economy and an excellent advertisement for you and the railway company.

13. Don't forget to read the previous twelve "Don'ts" frequently enough to memorize them, and to industriously and energetically make them effective, and insist on your subordinate staff doing likewise.

Registration, American Railway Association

Division V—Mechanical

Armstrong, A. G., Shop Supt., A. T. & S. F., Ritz-Carlton.
Babcock, W. G., M. M., N. Y. C., Haddon Hall.
Bachurst, C., Mech. Insp., South Australian Railways, Ambassador.
Baker, C. H., Shelburne.
Bardo, C. L., G. M., N. Y., N. H. & H., Seaview.
Barnhart, S. H., Asst. Val. Engr., N. & W., Blenheim.
Basford, G. M., Lima Loco. Wks., Marlborough.
Bevan, T. D., Eng. Power Houses, C. of N. J., Princess.
Blackburn, J. W., Supr. Loco. Oper., Erie.
Broo, C. W., G. C. F., N. K. P., Sterling.
Brown, R. M., Asst. S. M. P., N. Y. C., Marlborough.
Buck, E. R., Asst. M. M., Penna.
Burket, C. W., Asst. M. M., Penna., Morton.
Cougle, Bertus, For., L. V.
Crone, S. A., Dennis.
Cross, C. W., Supor. of App., N. Y. C., Haddon Hall.
Croumey, F. P., G. F., N. Y. N. H. & H.,Princess.
Cull, J. J., G. F., N. Y. N. H. & H., Richmond.
Cunningham, W. P., S. M. P., Monongahela, Ambassador.
Dailey, E. B., Asst. to Dir. of Pur., S. P., Traymore.
Daily, C. P., M. M., C. R. I. & P., Ambassador.
Dambach, C. O., G. S., P. & W. Va., Strand.
Davis, D. W., M. M., L. V., Haddon Hall.
DeVilbiss, E. B., S. M. P., Penna., Chalfonte.
Dice, Agnew T., Pres., P. & R.
Dickerson, T. B., Supt. Shops, C. of N. J., Boswell.
Dickert, C. L., S. M. P., C. of Ga., Traymore.
Diven, James B., M. M., Penna.
Dixon, W. J., Asst. M. M., B. & O., Princess.
Dobson, F. L., M. M., Penna., Chalfonte.
Doherty, E. H., Shop Supt., N. Y. C. & St. L., Shelburne.
Droege, John A., G. S., N. Y. N. H. & H., Runnymede.
Emrich, G. S., Asst. M. M., Penna.
Fritchey, F. W., M. M., B. & O.
Ettinger, R. L., Ch. Mech. Eng., Southern, Dennis.
Evans, J. R., Ch. Fuel Insp., C. & O., Strand.
Ewing, J. J., Eng. of Tests, C. & O., Seaside.
Eyerly, W. S., Asst. Supt. Shops, B. & O., Schlitz.
Fahy, M. J., G. F., N. Y. N. H. & H., Richmond.

Farrell, Jno., G. F., Penna., K. C. Hall.
Faus, H. W., Spcl. Eng., N. Y. C., Ambassador.
Finnegan, J. A., G. F., B. & O., Ritz-Carlton.
Fletcher, C. C., Ch. Cl. M. P. R. S., N. Y. C., Marlborough.
Forche, J., G. C. F., N. K. P., Sterling.
Fox, G. P., Shop Supt. C. D., N. Y. C., Pennhurst.
Francis, George E., G. F., Penna., Martinique.
Froker, J. O., Ch. Elec., T. & P., Flanders.
George, W. A., M. M., Jacksonville, Term., Princess.
Gloeckler, H. C., G. F., Penna., Morton.
Goodrich, Max, M. M., N. Y. C., Eastborn.
Gage, R. G., Elect. Eng., C. N. R., Haddon Hall.
Gallagher, F. S., Engr., N. Y. C., Traymore.
Gray, B. H., S. M. P., G. M. & N., Ambassador.
Gray, C. B., M. M., Penna., Marlborough.
Greenwood, H. F., Shop Supt., N. & W., Chalfonte.
Hankins, F. W., Gen. S. M. P., Penna., Dennis.
Hart, John B., Supt., E. J. J. R. R. & Term. Co., Dennis.
Hatch, C. E., Ch. Matl. Insp., N. Y., N. H. & H., Traymore.
Hauer, E. H., Ch. Draftsman, C. & O., Seaside.
Hawk, E. T., G. F., P. & R., Monticello.
Hedley, Frank, Pres., Inter. Rap. Trans., Marlborough.
Heinbach, W. F., M. M., P. & R., Schultz.
Helme, Chas., M. M., L. V., Haddon Hall.
Herr, E. D., Penna., Goodfellow.
Hines, J. P., M. M., B. & O., Marlborough.
Hogan, F. R., Asst. R. F. E., P. & R., New Princess.
Hubert, H. J., Asst. Eng. M. P., Penna.
Hunter, G. S., M. M., C. & S., Seabrooke.
Jones, D. S., Asst. to Pres.,B. R. & P., New England.
Jones, L. B., M. M., Penna., Arlington.
Jumper, F. J., Spl. Engr., N. Y. C. & St. L., Ambassador.
Kauffman, J. O., For., Penna., Loraine.
Keiser, C. B., S. M. P., Penna.
Kelly, P. M., Insp. M. P., C. of N. J., Princess.
Kirkland, A. W., S. M. P., A. B. & A., Ambassador.
Lang, W. C., G. C. I., P. & L. E., Shelburne.
Leach, J. T., Asst. M. M., Penna.
Lee, R. S., G. F., Erie.
Lovell, Alfred, Knickerbocker.
Manchester, H. C., Traymore.
Marriott, F. I., Spec. Equip. Insp., C. & O., Seaside.
Martin, Wm., Genl. Mech. Insp., M. P., Haddon Hall.
McDowell, J. L., G. C. F., K. & I., Osborne.
McNicholl, C., M. M., Lake Term., Strand.
Mears, R. J., Ch. Draftsman, N. Y. C.
Moore, H. C., Treas., P. & W. Va., Strand.
Moses, E. P., Asst. Eng. R. S., N. Y. C., Pennhurst.
Mullen, D. J., S. M. P., C. C. C. & St. L., Traymore.
Murphy, F. K., Asst. S. M. P., C. C. C. & St. L., Traymore.
Myers, H. E., M. M., L. V., Dennis.
Nicholas, R. H., Asst. M. M., C. of N. J., Brady.
O'Brien, W. J., S. M. P. & R. S., N. Y. C., Haddon Hall.
Odell, P. E., G. M., G. M. & N., Ritz-Carlton.
Olsen, W., Supt. Power Plants, N. Y. C., Shelburne.
Peach, J. F., Supvr. Mfg. E. S. & E., B. & O., Knickerbocker.
Powell, G., M. M., The Pullman Co., Knickerbocker.
Rafferty, C. D., M. M., A. C. & H. R., St. Charles.
Reed, I. N., Mech. Mgr., N. Y. N. H. & H.
Riegel, S. S., Mech. Eng., D. L. & W., Runnymede.
Rodenbaugh, H. N., G. M., F. E. C.,Brighton.
Sandhas, Harry L., Gen. Insp., C. of N. J., Lexington.
Schad, T. W., M. M., B. & O., Traymore.
Schneider, G. A., M. M., Penna., Sterling.
Schum, H. S., G. F., Penna., Lorraine.
Sealey, G. L., Asst. Elec. Eng., P. & R., Clarendon.
Sechrist, T. O., Asst. Supt. Mech., L. & N., Chalfonte.
Sederquest, W. B., M. M., N. Y. N. H. & H., Glaslyn.
Shuler, E. A., M. M., The Pullman Co., Knickerbocker.
Smith, J. H., Ch. Draftsman, C. of N. J., Worthington.
Smith, M. A., Genl. Mech. For., I. C.
Smock, F. A., G. F., Penna.
Steins, C. K., Asst. M. M., Penna., Chalfonte.
Stevens, F. J., M. M., L. I.
Stoll, Geo. J., G. F., Penna.
Terwilliger, Geo. E., Genl. Air Brake Supvr., N. Y. N. H. & H., New Haven, Chalfonte.
Van Valin, H. D., Marlborough.
Voelker, H. R., G. F., Penna., Craig Hall.
White, R. B., G. M., N. Y. Div., B. & O., Shelburne.
Whitener, H. E., Asst. M. M., B. & O., Princess.
Williams, M. E., M. M., P. & R., Elberon.
Willson, L. M., M. M., W J. & S. S.

Division VI—Purchases and Stores

Butterworth, J. A., Ch. Cl., P. A., Southern, Traymore.
Garnham, L. S., Supvr. Sec. C. Pur. Dept., Penna.
Holzemer, J. F., P. A., N. Y. C., Traymore.
Hughes, P. E., Commissary Agt. Pur. Dept., Penna., Apollo.
Jones, W. F., G. S., N. Y. C., Chalfonte.
Lehman, E. H., G. S., N. Y. C., Traymore.
Montgomery, S. A., Supvr. Sec. A. Pur. Dept., Penna.
Telford, A., Asst. G. P. A., Southern, Marlborough.
Trainor, John E., Req. Supt. P. A., Penna.

Special Guests

Adair, John G., R. R. Equip. Expert, War Dept., Jerome.
Adzuma, Yosak, Mech. Eng., South Manchuria, Chelsea.
Alcorn, A. E., Cl. Pur. Dept., Penna.
Anderson, W. L., R. F. E., Penna.
Apgar, A. R., Elect., Penna.
Arless, V. K., Penna.
Austin, John B., For., Penna.
Baker, H. F., Insp., D. & H., Ambassador.
Barrow, T. H., Insp. B. & O., Glaslyn.
Bartlett, Albert, Air Brake Instr., Penna.
Biemiller, Harry, Asst. For., P. & R., Lexington.
Biemiller, Jno., Asst. For., P. & R., New Princess.
Blydenburgh, R. R., Gang For., Penna.
Bowman, John F., Chi. Asso. of Commerce, Marlborough.
Brendel, O., For., C. of N. J.
Brenholtz, Thomas S., Draftsman, P. & R.
Brown, W. G., Supvr. Matl., B. & O.
Buck, G. A., Div. Frt. Agt., P. & R.
Burleigh, R. B., Traymore.
Butts, H. M., Ret., N. Y. C., Craig Hall.
Carlson, E. H., M. M., Penna.
Clark, J. P., Supr. Sig., P. & R.
Conlin, J., Spec. Insp., B. & O., Jerome.
Connolly, Wm. B., Jr., For., Penna.
Connor, R. A., Shop Draftsman, B. & O.
Davis, W. L., For., Penna., Martinique.
Donahue, M., Station Master, N. Y. C.
Doyle, E., For. Erection, C. of N. J., Warwick.
Einwalchter, F. H., Draftsman, B. & O., Louvan.
Eiseman, C. R., For. Pipe Shop., Penna.
Emmerich, E. E., Ch. Insp. Eff. Bureau, B. & O., Craig Hall.
Faulkner, Wm. J., For., Southern, Tabor.
Finn, W. E., Ch. Cl., B. & O., Traymore.
Fisher, Frank L., Eng., C. & N. W., Ambassador.
Fitzgerald, D. W., Asst. For. Penna., Schlitz.
Floyd, Jos., Elect., C. of N. J.
Forshee, I. C., Tel. & Tel. Eng., Penna., Haddon Hall.
Freeman, Samuel, Asst. R. F., Penna.
Frenzer, P. F., Supt. Tele., U. P., Haddon Hall.
Gaines, E. C., For., N. & W.
Gallagher, John E., R. F. E., P. & R., Martinique.
Geiselman, F. R., Draftsman, B. & O., Louvan.
Geist, J. R., Spec. Pass. Car Insp., B. & O., Knickerbocker.
German, William M., P. & R., Somerset.
Glenn, Thomas, B. & O.
Goda, P. H., Asst. Gen. For., Penna.
Gordon, J. W., M. M., A. C. & S.
Gordy, H. P., Draftsman, B. & O., Louvan.
Gorton, Chas. E., Haddon Hall.
Goshorn, H. R., Gen. Claim Agt., P. R. T.
Goshorn, L. R., Treas., City of Pittsburgh.
Gotwals, W. D., Ch. Cl. Transp. Dept., P. & R.
Gould, F. E., Draftsman, N. Y. C.
Gulick, Harley, Inst. Tr. Serv., Penna.
Hawk, Charles D., Monticello.
Hawk, William, Monticello.
Hawman, Allen M., Asst. Ch. Cl., P. & R.
Heinbach, Wilfred F., Schultz.
Heiser, C. E., Supvr. of Elec. Equip., P. & R., Elberon.
Herter, F. J., Ch. Draftsman, N. Y. C. & St. L., Haddon Hall.
Heskett, J. Z., Insp., B. & O., Glaslyn.
Hibbs, C. E., Asst. R. F. E., Penna., Morton.
Higgs, G., Asst. R. F. E., C. of N. J., Boswell.
Hix, C. E., Supt. Trans., S. A. L.
Holtzapple, G. L., For., Penna., Martinique.
Holzbach, J. A., B. & O.
Horton, Clarence, R. F. E., P. & R., Princess.
Hunter, Fred., C. & S., Seabrooke.
Kausch, Nicholas, P. & R.
Lantelme, J. B., For., L. I., Iroquois.
Leard, H. S., Supvr. of Pass. Oper., S. A. L.
Lesher, Herbert B., Electr., P. & R.
McCabe, J. J., Ch. Insp. Eff. Bureau, B. & O., Craig Hall.
McConnell, Wm. H., Cl. M. P. & R. E., P. & R.
McCourt, David B., Asst. Traf. Mgr., Interocean Oil Co., Strand.
McCue, Thomas B., Asst. For., P. & R., Stanley.
Meder, F. R., Penna.
Meehan, F. R., For., L. I., Iroquois.
Metzger, W., For., C. of N. J.
Morningstar, E. E., Asst. Ch. Mech. Draftsman, B. & O., Louvan.
Morrissey, T. A., Cl. M. P. Dept., L. V.
Morton, R. C., Draftsman, B. & O., Louvan.
Moses, Winfield H., Pennhurst.
Offutt, R. J., Shop Insp. Eff. Bureau, B. & O., Craig Hall.
O'Neil, Bernard J., Car Insp., P. & R.
Parker, W. V., For., W. J. & S. S.
Pennell, S. B. Draftsman, N. Y. C.
Phillips, C. F., Spec. Eng., N. Y. C., Y. M. C. A.
Pietsch, T. A., For., B. & O., Arlington.
Price, Chas. M., Ch. Cl. M. P. Dept., P. & R.
Rehm, Christian, Act. For., L. I.
Robbins, Harry G., N. Y. C., Seaside.
Roberts, W. N., Ret. For., Penna., Westminster.
Roeser, E. J., Draftsman, P. & R.
Sauer, A., P. & L. E.
Schaeffer, Karl A., P. & R.
Schum, Daniel, M. M., W. W. V., Taylor Villa.
Shadle, F. S., Elect., P. & R.
Shank, Edward L., Asst. For., P. & R.
Shelton, F. M., Supvr. Loco. Supplies, D., L. & W., Haddon Hall.
Shepard, H. A., Genl. Supt. Elec. Trans., N. Y., N. H. & H., Haddon Hall.
Shepherd, J. E., C. of N. J., Bothwell.
Siebenhaar, John P., Ch. Draftsman, L. I., Kentucky.
Sinks, G. H., City Pass. Agt., B. & O.
Smith, J. J., Ch. Insp. Eff. Bureau, B. & O., Craig Hall.
Smith, Stanley E., C. of N. J., Worthington.
Souders, Eugene N., P. & R., Somerset.
Spaide, George S. W., R. H. F., P. & R.
Starkey, J. A., Shop For., W. J. & S. S.
Stumpf, Carl, For., L. I.
Surran, C. Bruce.
Taylor, H. L., Tool Supvr., B. & O., Kentucky.
Thayer, J. S., Mech. Dept., B. & O., Clarendon.
Truitt, J. L., M. P. Insp., Penna.
Van der Heyden, Thomas, For. Elect. Eng., Penna.
Wagner, C. H., Penna.
Wambaugh, R. H., Shop Insp., B. & O., Haddon Hall.
Watkins, Thomas, R. H. F., P. & R.
Weber, W. W., Asst. For. M. P. & R. E., P. & R., Stanley.
Wenzel, C. F., For. Car. Insp., Penna., Richmond.
Whitaker, H. H., Draftsman, N. Y. C.
Whiteman, R. C., Insp., B. & O., Glaslyn.
Wible, T. E., Ch. Insp. Eff. Bureau, B. & O., Craig Hall.
Wilson, H. A., Penna.
Wilson, T. B., Southern, Shelburne.
Wise, A. J., Gen. For., W. M., Kingston.
Woods, Harry, Dept. Plants and Struct., N. Y. City.
Worrell, H. J., Penna.
Wyrough, H. M., Asst. R. F. E., Penna.
Zeigler, C. J., Ch. Elect., F. E. C.

Conventionalities

Paul A. Bevan, assistant works manager of the Westinghouse Air Brake Co. at Wilmerding, put in his appearance at the convention Wednesday. This is his first visit to the convention in ten years.

I. T. Cruice, railway manager for the mid-western territory of the Independent Pneumatic Tool Co., was taken to the Atlantic City hospital Wednesday with a severe case of bloodpoisoning.

In addition to the five representatives of Japanese railways mentioned in Friday's *Daily* as giving interested attention to exhibits, there are also registered two others: I. Watanabe and S. Yoneoka, engineers, South Manchuria Railway.

Herman H. Westinghouse, chairman of the board of the Westinghouse Air Brake Co., who has been a rather regular attendant at conventions for many years, was able to make only a short stay this year. He was at the Marlborough-Blenheim on Thursday and Friday.

Col. B. W. Dunn, chief inspector, Bureau of Explosives, who since his appointment to this responsible position many years ago has done more than any man or any other organization to inject safety practices into the handling of explosives, is noted as among those registered.

H. E. Doerr, formerly chief mechanical engineer and for a year or so general superintendent of the Scullin Steel Co. varies the exercise of his inventive faculties by switching them from cast-steel truck side frames to golf clubs. He is the inventor of the Doerr truck and the "Top-em" putter.

Among the operating officers attending the convention is H. N. Rodenbaugh, general manager, Florida East Coast and vice-president Jacksonville Terminal Co. Mr. Rodenbaugh has been active in the work of the American Railway Engineering Association, but has not attended previous conventions of the mechanical division.

Charlie Hogan, manager, department of shops and labor of the New York Central, the engineer who drove the 999 at 112 miles per hour, is here collecting his outstanding debts. On meeting Wm. Garstang Thursday night at the ball he demanded the 17 cents due him from the game of pool they played at Niagara Falls twenty-two years ago.

Guy Gregory, who was connected with the Cleveland Pneumatic Tool Company for about ten years, changed his position on June 1 and is attending the convention as a special representative of the Elwell-Parker Electric Company. He will be associated with the president, Lucian Brown, at the New York office.

Joe Ennis, the engineering vice-president of the American Locomotive Company, has been in one constant blush from the compliments he has been receiving on that *beautiful* engine on the Track Exhibit. Mr. Ennis always comes back with the statement that she acts as *beautifully* as she looks. Certain it is that history is in the making on three-cylinder designs.

A. W. Clokey, of the American Arch Company, motored from Chicago with his wife and ten-year-old daughter, Mary Wilson. He just sort of sauntered along, as he said, making the trip in three days. An average of over 300 miles a day in a "fliv" is some saunter, we'll say. Mrs. Clokey and the daughter are at Salisbury, Md., during the conventions.

E. W. stands for electric welding and also for Ernest Wanamaker. The two are inseparable in the minds of the many who are acquainted with him. In addition to welding, Mr. Wanamaker is now giving considerable attention to the motorization of light railways. He was one of the party making the trip in the Sykes two-car gasoline motor train from Chicago to Atlantic City.

William Garstang, formerly superintendent of motive power, Big Four, and past president of the American Railway Master Mechanics' Association, who several years ago retired from active railway service, is in attendance at the convention, enjoying the renewal of acquaintance with his former fellow officers and with none of the cares of associational of official connection to bother him.

Ernest Lunn, electrical engineer of the Pullman Company, is attending the convention this year in the capacity of president of the Association of Railway Electrical Engineers. While the lighting of Pullman cars is Mr. Lunn's chief concern, he has of late been demonstrating what can be done with radio apparatus on moving trains. He received a telegram yesterday stating that a car equipped with radio receiving apparatus was in constant touch with one broadcasting station or another throughout the entire trip from Chicago to Boston.

R. E. R. Packer, Q. & C. Company, has turned himself into a railway operating officer and now spends his time running a three-level electric railway that brings back our boyhood longings every time we look at it. Prior to becoming operating officer of the Q. & C. Railway, Mr. Packer held various positions as chief designer, electrical engineer, master car builder, master mechanic, engineer maintenance of way and many other positions. When not earnestly engaged in keeping people's fingers out from under the car wheels, he spends his time explaining how each separate train is loaded exactly the same, operates on the same power but that each is fitted with miniature duplicates of different types of side bearings to illustrate the effect of sidebearing friction on train operation.

Registration as a life member of Division V—Mechanical, indicates two things: First, that the member who can so register is proud of the association to which he belonged many years; and, second, that the association as constituted at present recognizes his active work in the past and is proud of him. Among those entitled to this distinction as disclosed by the registration list are found the names of William Schlafge, whom one naturally associates with the Erie, and who was president of the Master Mechanic's Association from 1916 to 1918. He is as active as ever although the conversion of the Meadville shops to contract work, of which he is in charge, appears technically to suspend his active membership functions. Then there are H. W. Curry, Northern Pacific, and C. E. Fuller, Union Pacific, the latter of whom has been president of both the old associations; of Broderick Haskall, long a mechanical representative of the Michigan Central; of D. F. Crawford, Pennsylvania, whom each of the former associations had honored with the presidency. The history of the last-named is somewhat different from that of some of the others in that he has transformed his activities from the railroad to the manufacturing field, having found the problems of the automatic stoker of sufficient magnitude to demand an undivided attention.

The Conventions an Institute of Economy

Properly Utilized Can Be a Large Factor in Securing More Efficient and Economical Operation

Official encouragement of attendance at the mechanical conventions by railway officers is the subject of correspondence between Gray Silver, Washington representative of the American Farm Bureau Federation, and President Aishton, of the A. R. A. Mr. Silver urges the fullest use of the convention and exhibits by mechanical officers to the end that operating economies may ultimately give the farmer lower freight rates. Mr. Aishton in his address before Division V, Mechanical, on June 11, quoted from the correspondence and declared that the manufacturers' exhibit is an important factor in railway efficiency and economy.

The Silver and Aishton letters and an extract from Mr. Aishton's speech are published by the Railway Business Association for distribution at the convention, under the title, "The Atlantic City Conventions—An Institute of Railway Economy."

Mr. Aishton's address has already been printed in the *Daily*. The Silver-Aishton correspondence follows:

The Letter to Mr. Aishton

Dear Mr. Aishton:

The deep interest of the farmers of the country in reduction of railway operating cost and hence in railway mechanical progress, because of its influence upon railway freight rates, leads to the inquiry whether the railway companies sufficiently encourage appropriate officers of the operating and mechanical departments to keep abreast of new developments by attending their various conventions and observing manufacturers' exhibitions held in connection with such meetings.

The former president of the American Farm Bureau Federation, James R. Howard, in a recent address, spoke in part as follows:

Lower Operating Cost

"We are asked to pay higher freight rates than those to which we have been accustomed. We are told that the increased railway income is necessary in order to attract capital for just such improvements. What the thoughtful farmer has in mind is reduction in railway operating costs. Therein he sees the only hope for ultimate rate reduction which he demands. He is thinking of the improvements most obvious to him, such as hydro-electric power; but he is coming to know, and I promise you he will increasingly know, something about the more intensive progress in every branch of transportation science. To you gentlemen the confidence and good will of the farmers are vital. You hope they will be patient about rates. You invite their co-operation for a respite from railway legislation. Towards both those problems the attitude of agriculture will be profoundly affected if the farmers are convinced that the strengthened credit arising from the higher rates is to be used in devoting capital to improvements for economy."

A Channel For Recommendations

During federal control of railroads in 1919, "to provide," as an official circular explained, "a responsible channel through which the Director General may obtain recommendations for the advancement of railroad practice," the concerted studies of the railways were organized by departments of work and railroads under federal control were "directed to be represented and participate in the activities of each section through their proper officers."

Later in the year announcing the convention of the mechanical section then about to be held in Atlantic City, a circular to the regional directors contained the following:

To Observe And Report

"It is desired that the representative members from the different railroads attend, as far as possible, and that other mechanical department officials who are members be permitted to attend, for at least a portion of the time, where they can be spared from their regular duties without adversely affecting the service. It is anticipated that there will be on exhibition the most complete collection of mechanical appliances that has ever been exhibited at one of these conventions, and a study of it will be of substantial value to the mechanical department officers who are in attendance."

"In order to obtain the greatest possible amount of benefit from this convention, it is desired that each member present below the rank of superintendent of motive power shall, on his return from the convention, make a written report to the superintendent of motive power, relative to the new devices which he inspected at the convention, or ideas which he obtained from the discussion which can be applied with profit to the work under his direction.

"The superintendent of motive power will make a digest of the various subjejcts presented in this way, so that those which can be profitably adopted may be given consideration, sending a copy of it to the Assistant Director, Division of Operation, in charge of the mechanical department, for the use of the Committee on Standards for locomotives and cars.

"Will you please issue the necessary instructions?"

Stationary Exhibit Indispensable

This official order was a formal recognition of the indispensable conditions under which appliances of such size and weight can be inspected by those charged with responsibility for mechanical efficiency and economy on these several railways. The manufacturer's representative cannot carry the goods from road to road. Photographs, blue prints and models give at best a limited understanding of the device. It is essential that from time to time the railway officers may observe the appliance itself in operation. Of great importance is the opportunity for the younger mechanical men, from among whom must come the officers of the future, to see the demonstrations with which they can not become familiar except through an exhibition. A great economy in selling expense is effected by relieving the manufacturer of the cost of having sales engineers visit the mechanical men in their shops.

The Atlantic City Institute

We are informed that the American Railway Association as reorganized since the relinquishment of the roads to their owners now holds in June at Atlantic City, at Chicago in March and at these and other times and places, conventions of their several sections, at which manufac-

turers' displays are given. We understand that the exhibition of mechanical devices applicable to cars and locomotives, to which reference was made in the circular just quoted, are conducted for a week in June in Atlantic City. We are informed that the sessions take the form of an institute at which delegates read and discuss prepared papers upon standards and practices affecting construction, use and interline exchange of rolling stock and that not only are these debates highly educative to those participating in them but that also the practical results through many years have been recommendations of standards generally at once adopted and constituting steady and valuable advance in railway efficiency and economy. We understand that the schedule of sessions is so arranged as to give the delegates free time for study of the mechanical exhibits which manufacturers display upon the pier and that inventors, engineers and other specialists are in attendance to demonstrate and explain the appliances. We have been particularly interested to note that these exhibits attract large numbers of manufacturers who inspect them with a view to development in their own mills. From the point of view of the shipper mechanical progress is important in the mills which provide the railways with equipment, appliances and shop machinery.

We learn that a large proportion of the railway and industrial officers attending are accompanied by ladies of their families and that the gathering is on a correspondingly high plane of simplicity and propriety.

It is our impression that other sections of railway officers and the exhibits at their conventions are similarly valuable.

Encouragement to Attendance

Inquiry seems to indicate that while some of the railway companies instruct their mechanical officers to attend these conventions and make systematic reports, to a large extent attendance is voluntary. Do you not agree with us that shippers, whose interests are directly affected by railway mechanical progress, are warranted in suggesting that all the roads follow the example of the systems which in proper ways encourage participation in these conventions as an official duty? We would be gratified if you would arrange to have this subject discussed by your Association and would be glad to learn what view prevails.

Yours truly,

American Farm Bureau Federation,

Gray Silver.

Mr. Aishton's Reply

My dear Mr. Silver:

I am just in receipt of yours of the 12th instant, having particular reference to the convention of the Mechanical Division of the American Railway Association at Atlantic City, June 11th to 18th, and with specific reference to the advisability of encouraging the attendance of the officers of the operating and mechanical departments of the railroads, that an opportunity be afforded them for observing the latest developments in approved devices affecting operating costs, through the observance of manufacturers' exhibits held in connection with these meetings.

Every effort of the railroads individually is being put forth to provide adequate and satisfactory transportation service at the lowest possible cost. Outside of the efforts put forth by the individual railroads in these directions, is the work that is being done by the railroads collectively through the American Railway Association—

First—Through the Car Service Division in the matter of adequate service and car distribution.

Second—Through the various activities of the American Railway Association to secure the greatest safety and economy in operation, and one of the means adopted is through the conventions, of which the one you mention, that of the Mechanical Division, is a notable example.

At the coming convention there will be a large variety of papers discussed on a very wide range of subjects, all of them having in mind better methods of doing the job and of securing more productivity out of every unit, and also of standardization and practices affecting plant, interline arrangements and exchange of rolling stock.

Highest State of the Art

There is in connection with this convention an exhibit of rolling stock, machinery, tools and other appliances, indicating the highest state of the art, and I think we can safely say that some part of the progress that has been made in the last decade, and which has resulted in giving the United States the best system of transportation there is in the world, has been due to the opportunities afforded by these conventions, and through the general interest shown by the active officers of the railroads and down through the ranks in taking advantage of these opportunities for education and information.

This convention is not the only one. In March there was a convention in Chicago of the Engineering and Maintenance of Way Association, also attended by exhibits, and I happen to know that this convention, their last one held, was one of the best attended they have ever had.

It is my prediction that the forthcoming convention at Atlantic City will likewise break former records for attendance, as these twin questions of adequacy of service coupled with the lowest possible cost are the outstanding things receiving the earnest attention of every railroad officer today.

I would further add that there is hardly a branch of the service in which this same work is not progressing on somewhat similar lines.

Prefers Voluntary Attendance

Your letter makes a direct suggestion that all railroads instruct their mechanical officers to attend these conventions. I am not entirely sure that the best results would be secured through this procedure. Every large railroad and a very large percentage of the small railroads are represented at these conventions by a number of mechanical, purchasing and other officers, including executives, through their innate desire and voluntary action to become acquainted with the latest improved methods and practices for producing economies, efficiency, and for providing more adequate service for the shippers, and the psychology of the thing, as I see it, is that that action is very much more effective than if they were there under specific instructions to attend.

Yours very truly,

R. H. Aishton

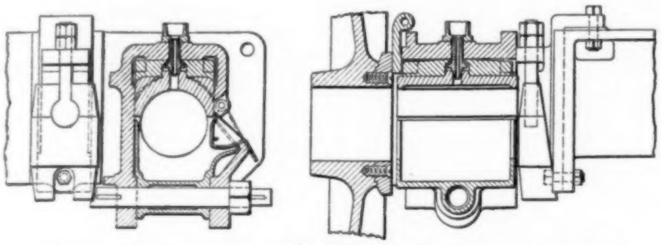
C. J. Mellin, who figures now on registration lists as an "affiliated member" attached to the personnel of the American Locomotive Co., still retains his old-time interest in all that concerns the development of the locomotive. He confesses now to getting some enjoyment out of leisurely inspection of whatever comes out as new from year to year, with, perhaps, some accent on the "leisurely."

Thursday was the anniversary of the birth of Lee W. Barber, president of the Standard Car Truck Company. Mr. Barber failed to specify what particular birthday he was celebrating in Atlantic City with his wife and relatives. Mrs. Barber is enjoying her fourth convention here. They are quartered at the Brighton. In the party are Mr. and Mrs. Frank L. Barber and their 13-year old son, John C. Barber. Young John C. has attended many of these conventions. Mr. and Mrs. James T. Milner are also members of the party.

Lehigh Valley Three-Cylinder Locomotive

Details of an Unusual Design Which Has Shown High Economy and Great Power Per Unit of Weight

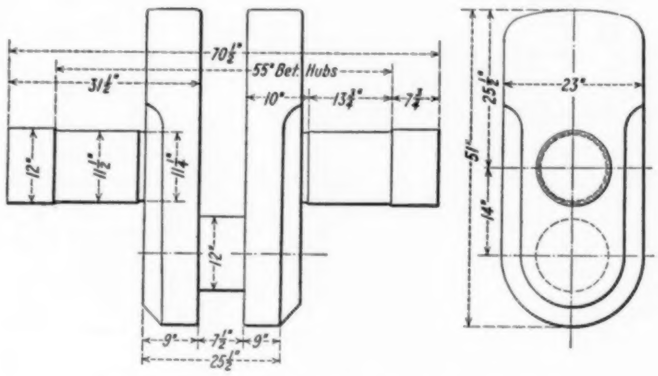
Nothing in the line of locomotive development has attracted more attention during the past year than that of the three-cylinder locomotive. The inclusion of Lehigh Valley locomotive No. 5000 among the track exhibits, together with the paper and discussion in the convention hall on Thursday, are most timely. This locomotive, which is of the 4-8-2 type, weighs 369,000 lb.; 246,500 lb. being on the driving wheels, 66,000 lb. on the leading truck and 56,500 lb. on the trailing truck. All



Detail of Blunt Truck Showing Axle Box and Lateral Adjustment

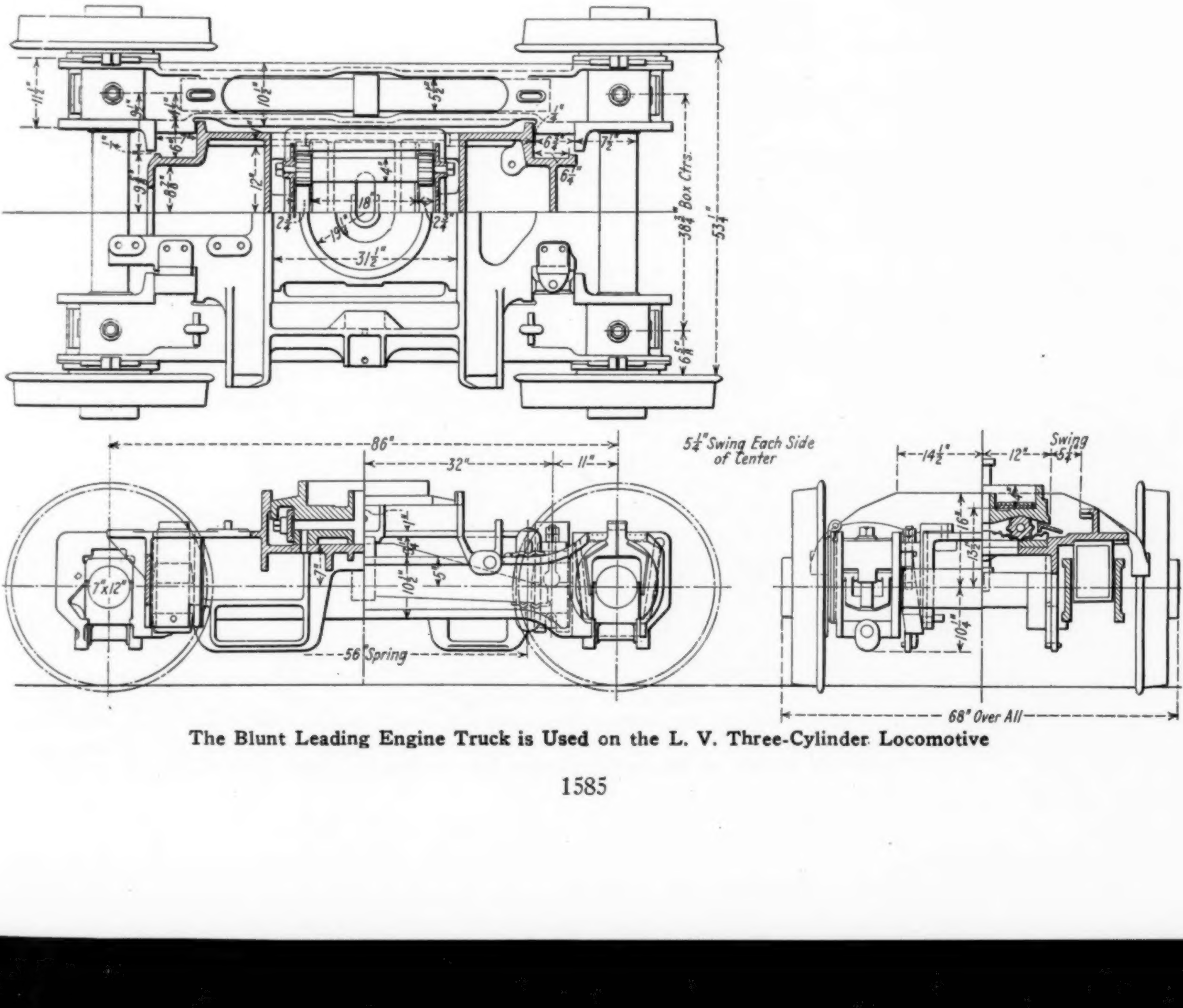
three cylinders are 25 in. by 28 in., and with 200 lb. boiler pressure, give a rated tractive force of 64,700 lb. The driving wheels are 69 in. in diameter, the trailing wheels 51 in. and the front truck wheels 36 in. The piston valves are 11 in. in diameter with 6 in. maximum travel. They are set for 1⅛ in. outside lap, ⅛ in. clearance and 3/16 in. lead in full gear.

The boiler, of the inverted wagon-top type, measures 82½ in. inside the first ring and is fitted with 230 2¼-in. tubes and 50 5½-in. flues, 21 ft. long. The firebox is 126⅛ in. long by 96¼ in. wide, and the grate area is 84.3 sq. ft. The total evaporative heating surface is 4,729 sq. ft., distributed as follows: 392 sq. ft. in the firebox and arch tubes, 2,832 sq. ft. in the tubes and 1,505 sq. ft. in the flues. The superheater surface is 1,294 sq. ft. The ex-

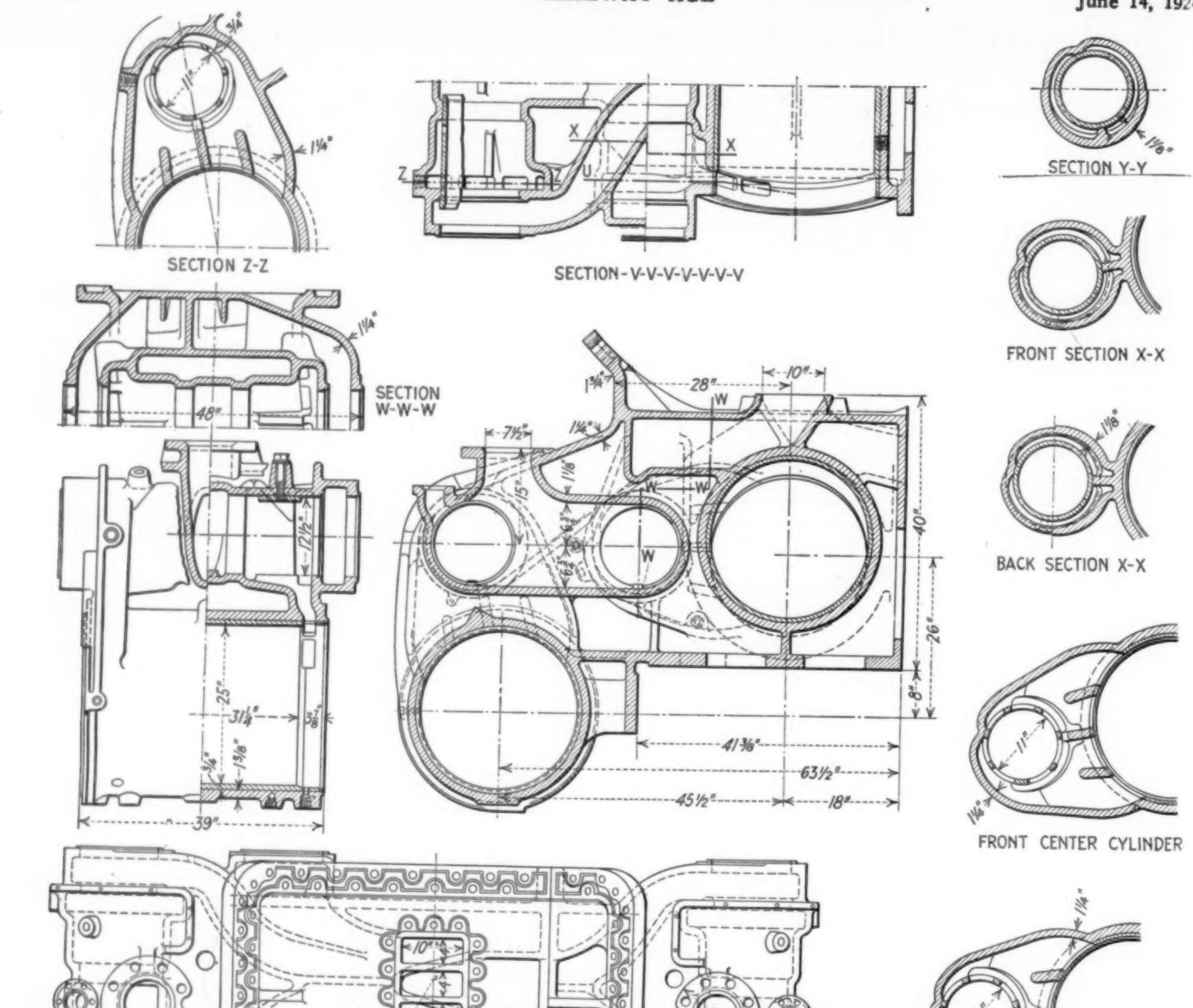


Construction of the Built-Up Crank Axle

cellent steaming qualities of the boiler have been demonstrated by several months' service in heavy traffic, frequently hauling milk trains of 22 loaded cars and 43 empty cars. The tonnage of the loaded trains averaged about 1,100 tons, while the empty train was about 1,550 tons.



The Blunt Leading Engine Truck is Used on the L. V. Three-Cylinder Locomotive



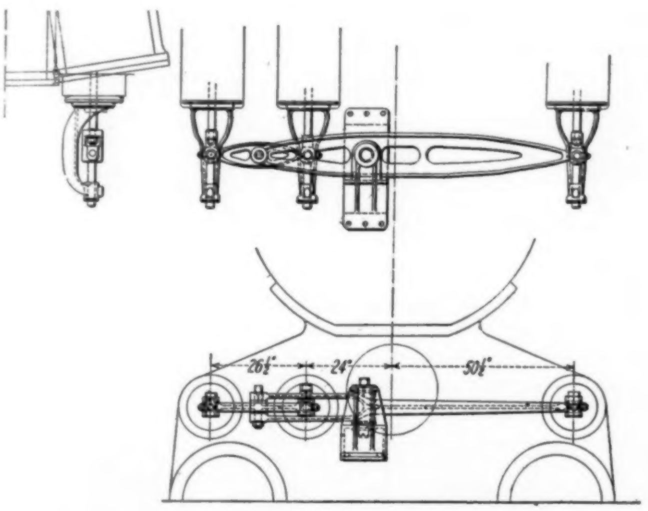
Cylinder Details of the Lehigh Valley Locomotive No. 5000

The runs of 145.5 miles had a schedule speed of 34.3 m.p.h. loaded and 27.7 m.p.h. empty.

A noticeable feature of this locomotive is the employment of the unusual factor of adhesion, only 3.81. This, of course, means a much greater tractive force per unit of weight than is possible in any locomotive of the two-cylinder type.

The cylinders are cast in two parts, with the division between the center cylinder and the left-hand outside cylinder. The center cylinder is elevated and inclined to permit the inside main rod to pass over the front driving axle and connect onto the second axle. Details of the inside main rod and the built-up crank axle are shown in accompanying drawings.

The cylinder casting provides an entirely separate steam chest for each valve, this in order to ensure proper lubrication of all valves and pistons. The exhaust passages lead to a common exhaust pipe of the annular type, which is



Lever Transmission by Means of Which the Two Ordinary Outside Gears Operate the Three Piston Valves

fitted with a nozzle having 10¼ in. outside diameter and 7⅛ in. inside diameter.

The valve gear is comparatively simple, the two usual outside gears being used to operate all three piston valves. This is accomplished by a lever transmission forward of the cylinders and connection to the valves as shown.

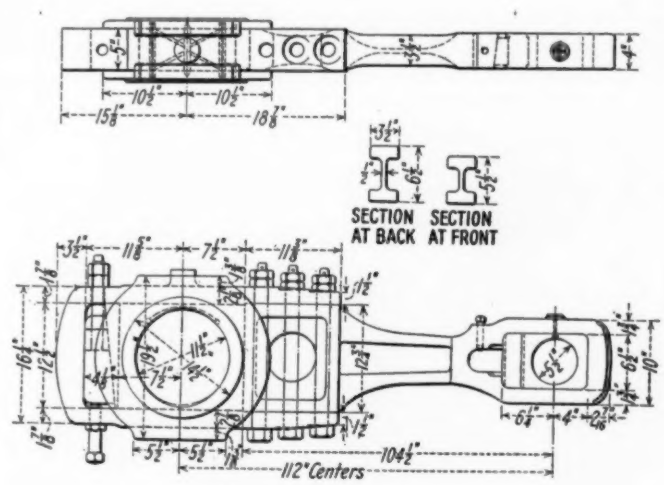
Blunt Trucks

The four-wheel leading truck and the trailing truck are of the new Blunt type. The engine truck center plate is carried on four gears, which travel over a special curved track. This arrangement permits of 5¼ in. travel each side of the center, and ensures proper centering when passing from curved to tangent tracks. As all parts remain practically horizontal, rolling is reduced to a minimum. A similar arrangement is used for centering the trailing truck.

Another new and interesting development is the Blunt journal box shown in one of the small illustrations. The cellar is held in place by a 2-in. pin and may be removed easily. The wheels are fitted with hub liners, and a tapered wedge permits of a readjustment for lateral wear. Provision is made for oiling the bearing at the top, while a lid on the sides gives ready access to the packing in the oil cellar.

Ralo-Acme Tank

The tank is of the water-leg type with a channel frame and has a capacity for 10,500 gal. of water and 15 tons of coal. The design is that of the Ralo Supply Company, New York, and provides for the Acme flanged top and bottom plates with welded corners. This arrangement



Middle Main Rod

permits of making repairs without removal of coal from the bunker or water from the tank. The outside shell is reinforced by gussets, which also act as supports for the top sheet and insure the maximum resistance to the surge of the water.

Frank L. Fay, president of the Greenville Steel Car Company, is here assisting with the demonstration of the Clark dump car. Ordinarily Mr. Fay is quite modest about his early experience, but he does tell this story about himself. It seems that while employed as an agent for the Nickel Plate Railroad at Painesville, Ohio, the wife of the minister called upon Mrs. Fay and after some conversation inquired as to the business that Mr. Fay was engaged in. Mrs. Fay said that her husband was the Nickel Plate agent. The conversation ran on a little further, when the minister's wife inquired, "Does Mr. Fay have charge of the work or does he do the nickel plating himself?"

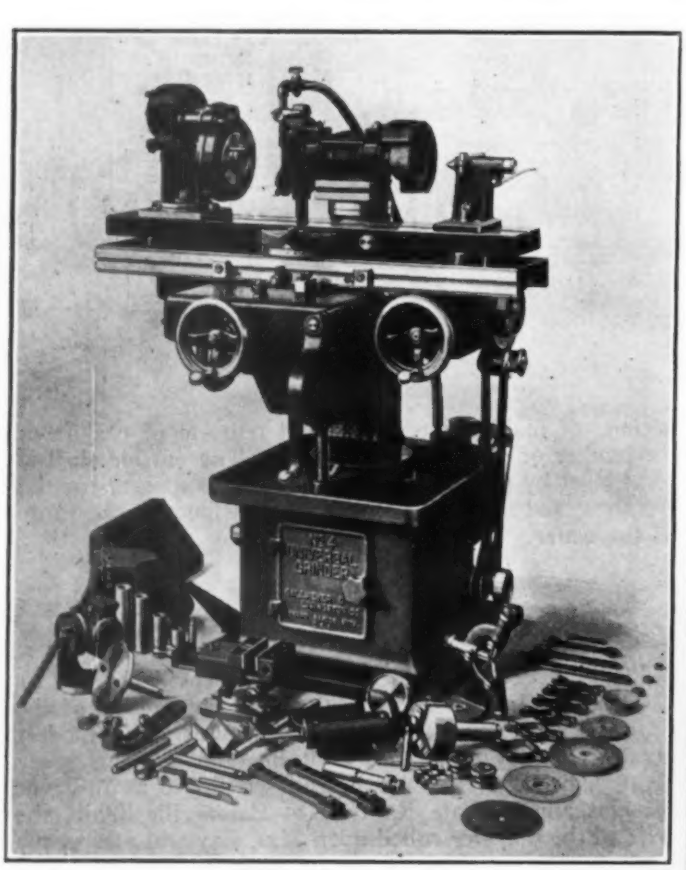
If the mechanical department of the Santa Fe fails to realize the maximum of possible benefit from the exhibits, it will not be because of any failure of opportunity or lack of encouragement on the part of officers in charge. A bunch consisting of about 25 representatives set out on Friday afternoon with the view to make the rounds of the whole show. The leading mechanical representative of another road went at the same proposition in another way. Without any desire to discourage attendance at the meetings, he told his men he could take care of that end of the proceedings, but he would depend upon them to see that he was informed of everything of interest represented on the pier. These instances seem to realize the goal which exhibitors have for many years been seeking to attain.

New Devices

Universal Tool Room Grinder

A compact, new two-spindle speed grinder for tool rooms is being exhibited this year by the Gallmeyer & Livingston Company, Grand Rapids, Mich., in which all overhead work is eliminated by driving the tool from a motor which is enclosed in the base of the machine.

The machine is so designed that it can be set in any angle or position to take care of all classes of work. The motor headstock swings on the base so that it can be set at any angle in relation to the table. It also provides for grinding on dead centers for cylindrical grinding or by a revolving spindle when having chuck or face-plate work to do. In operating the machine spindle the spindle head can either be swiveled or it may be locked in position and the knee swiveled, causing the saddle, table, etc., to swing around the inter-column.



A Two Spindle Speed Tool Room Grinder with Motor Contained in Base of Machine

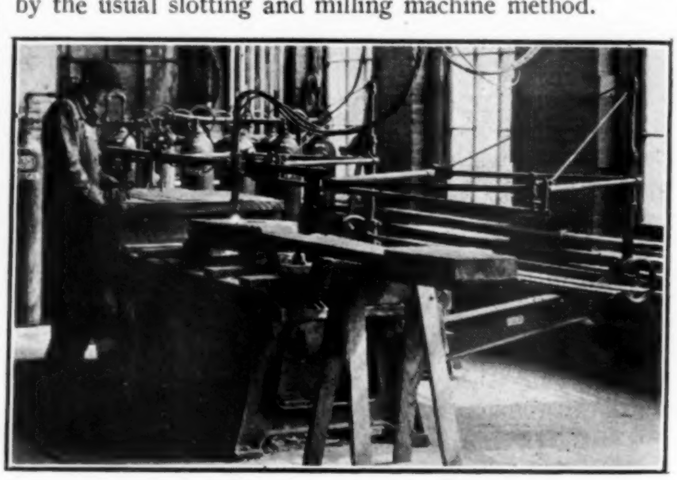
The machine is equipped for internal, cylindrical and reamer grinding. A heavy, rigid internal grinding attachment is supplied, which is equipped with ball bearings that tend to give greater accuracy. It is mounted on a tee slot on the head of the machine and driven by belt to the pulley on the main spindle. In performing cylindrical grinding work material 32 in. long can be carried between its centers. The work can be ground straight or at any depth of taper, and can be measured in either degrees or inches. The wet grinding feature and power feed are recommended for cylindrical grinding work. Straight or taper reamers may be ground by using a cup wheel. The table is swung around to the proper degree or taper per foot, which can be done very accurately by using the micrometer adjusting screws on the machine.

From the rear of the table the operator can control the longitudinal travel by a rapid action lever, and also operate the transverse or vertical movement. From the front of the table he not only can operate the vertical and transverse movement, but also has a choice of either slow or rapid action for the longitudinal travel.

Some of the dimensions of the machine are as follows: Size of table, 5½ in. by 42 in.; longitudinal travel, 24 in.; transverse movement, 9 in.; vertical movement, 10¾ in.; maximum swing, 10½ in. by 32 in., and maximum distance from center line of spindle to table, 10½ in.

The Airco-Davis Oxygraph Adapted to Railroad Practice

The Air Reduction Sales Company, New York, has applied the principle of acetylene cutting to the operation of finishing locomotive connecting rod forgings. Included in their exhibit is the oxygraph in operation, which performs the work more quickly than by the usual slotting and milling machine method.



Cutting a Crank Pin Hole in a Connecting Rod with an Oxygraph

The device is simple in construction and easy to operate. The machine in principle is a pantagraph with the arms having a ratio of one to one. The pantagraph is mounted on a table which can be raised and lowered by a ratchet device fitted to the base of the table. This device permits the cutting of any size of forging or casting that is commonly used in railroad practice.

The torch and the tracing device are fixed to the common bar of the pantagraph. The torch is one of the Airco standard acetylene cutters equipped with the universal movement. It can be moved along the common bar and set to cut at any position desired. A radial cutting bar can be put in the torch for cutting circles. The tracing device is the universal type driven by a General

Electric series wound universal motor. The motor is attached in series with the oxygen key on the torch which starts the motor as soon as the oxygen is turned into the torch. Attached to the motor is a variable electric speed governor which can be set to operate the tracing mechanism at any speed desired.

The illustration shows the device in operation. The forging to be cut is leveled on the base of the machine. No clamping of any kind is necessary. A standard template is used, around which the tracing device is propelled by the motor. The trimming of the outside stub ends is completed in one cut and gives a satisfactory finished appearance.

The principal feature of the device is the economical rate of cutting and consumption of gas. The speed and consumption of gas depend upon the thickness of the metals and finished desired. The most economical rate of cutting for connecting rod forgings is about four inches per minute. It takes approximately 4½ min. to cut out a six-inch diameter by 4½ in. thick crank pin hole. One-half inch of metal is left in the hole for finish. A rod can be completed by the oxygraph cutting operation in less than three hours. After the rod is completed it is annealed to relieve any stress which may have been set up by the local heating.

Locomotive Speed Indicator and Recorder

The Distance-Speed Recording Company, New York, is exhibiting its model K Loco-Recorder for use on road locomotives, and the model S-E Loco-Recorder for recording the movements of switch engines. The model K provides accurate, complete data as to time, speed, acceleration, deceleration and stops for every individual mile of the run. Every movement of the locomotive is indicated on the dial, as well as recorded on the tape in the proper order.

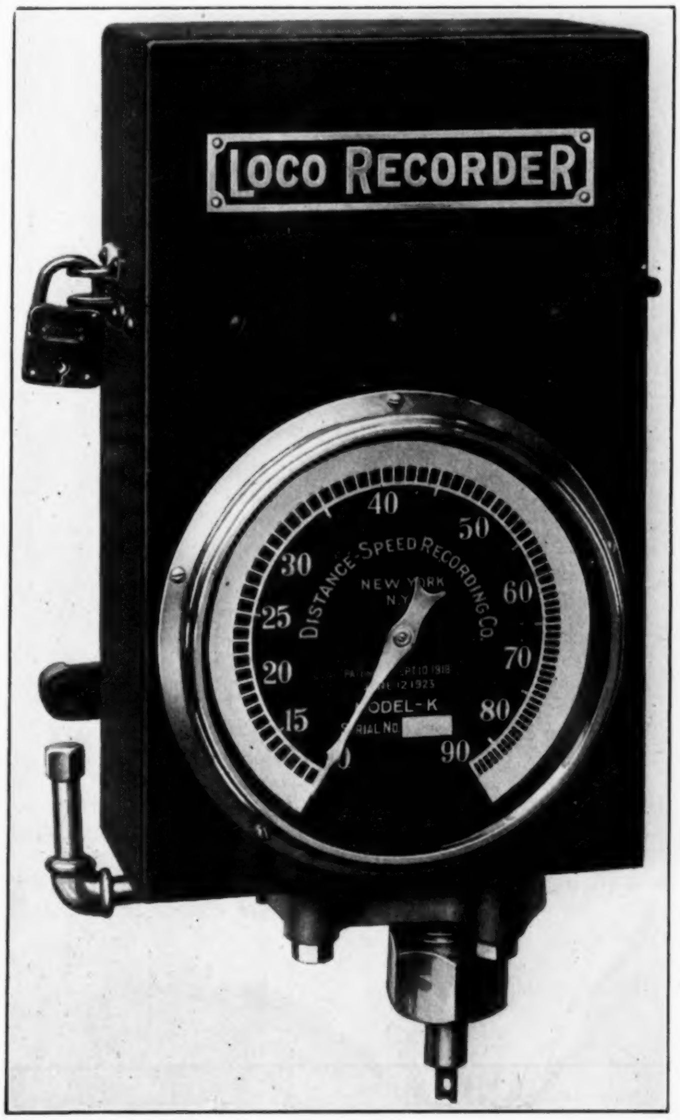
The speed indicating and recording mechanism is operated by a flexible shaft which is propelled by the driving mechanism running in contact with the periphery of one of the driving wheels. The indicating hand on the dial and the speed recording pencil are actuated by a centrifugal governor, which assumes a more nearly horizontal position as the speed of the locomotive increases. Against this movement is interposed a calibrated resistance so that all speed indications and records are uniform and accurate, and speed changes are instantly indicated and recorded. The time recording mechanism consists of a pencil actuated by clockwork which moves vertically across a tape in 10 minute strokes, ⅛ in. per minute, or at the rate of three complete cycles in an hour.

The recording tape is carried in the top of a locked case. Two independent graphs are inscribed on the tape, the upper one by the speed recording pencil, and the lower one by the time recording pencil. These two recording mechanisms are interlocked so that both records must always be the same.

The driving mechanism operates on the principle of surface speed; the wheel, which is of heat-treated alloy steel, in contact with the locomotive driving wheel tread merely acts as a measuring wheel. Since the principle involved is that of surface speed and not angular speed, the drive is applicable to wheels of any diameter running in contact with the rail. The drive consists of the drive wheel, a gear box, supporting bracket and flexible drive shaft. The entire mechanism is so applied that it is positive in operation and cannot cease to function except by the breakage of some part.

The model S-E Loco-Recorder is designed to make a record of switch engine movements over a period of 24 hours. It records, on a circular chart, the total time the locomotive is in motion during any 24-hour period, the duration of each movement, the time of day it occurred, and records the total idle time. An additional record is made of the distance traveled in either direction, the speed of operation and the total mileage, combined for any desired period.

The recording mechanism is composed of the clockwork which rotates the charts, the pencil operating



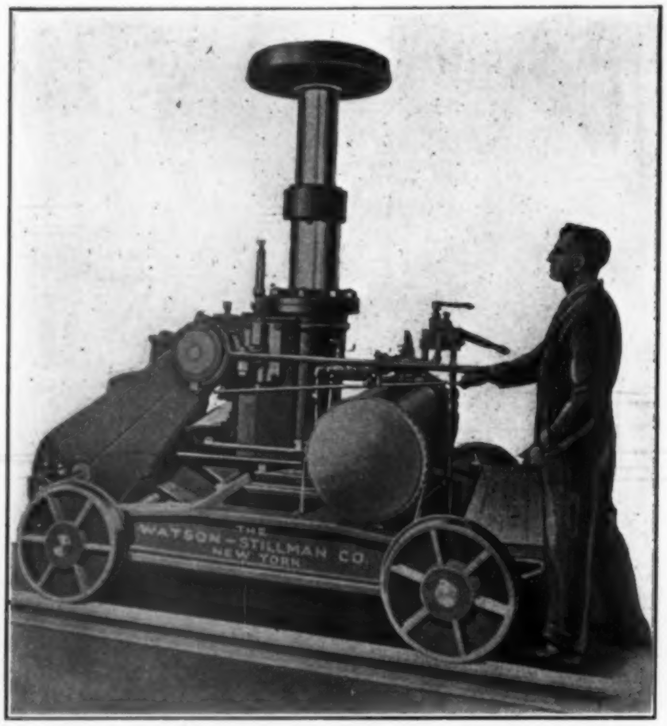
A Locked Metal Case Containing the Indicator-Recorder Mechanism is Located in the Cab

mechanism, the odometer and the clock self-winding feature. The driving mechanism is similar to that of the model K, with practically the same parts, and operates in a like manner.

Unlike the model K the recording mechanism of the model S-E is not installed in the locomotive cab, but is bolted to a bracket located on the frame or waist sheet in any position easily accessible and convenient to the driving mechanism.

The Wasco Pit Jack

The Watson-Stillman Company, New York, has just brought out a new pit jack that has a number of labor saving and safety features. This type of jack, on which a patent has been applied for, is a development of that company's standard line of pit jacks built since 1884 under the Vreeland patents. This jack is designed to be used in connection with a drop or traverse table and is shown in the illustration with a head to fit such a table. It can, however, be fitted with a saddle on the end of the ram so that it may be used in the old style of pit. It is designed to be operated by one man standing on the platform. It is self-contained except that it is necessary to connect it up to the shop air line, inasmuch as air is used to operate the hydraulic pump and to traverse the jack in the pit.



The Wasco Drop Pit Jack Can Be Operated By One Man From a Safe Position

The operation of the jack is simple, since the controls for raising and lowering the load as well as traversing the jack, are all within easy reach of the operator, who stands on the platform at the end of the jack. No manual labor is required. The jack rams are telescopic and are made with sufficient bearing in the cylinders to carry the maximum load rigidly. Hydraulic pressure is obtained by a two-plunger pump. All gears and chain drives are protected with sheet metal guards. These jacks are built in two sizes at the present time—30 and 50 tons capacity.

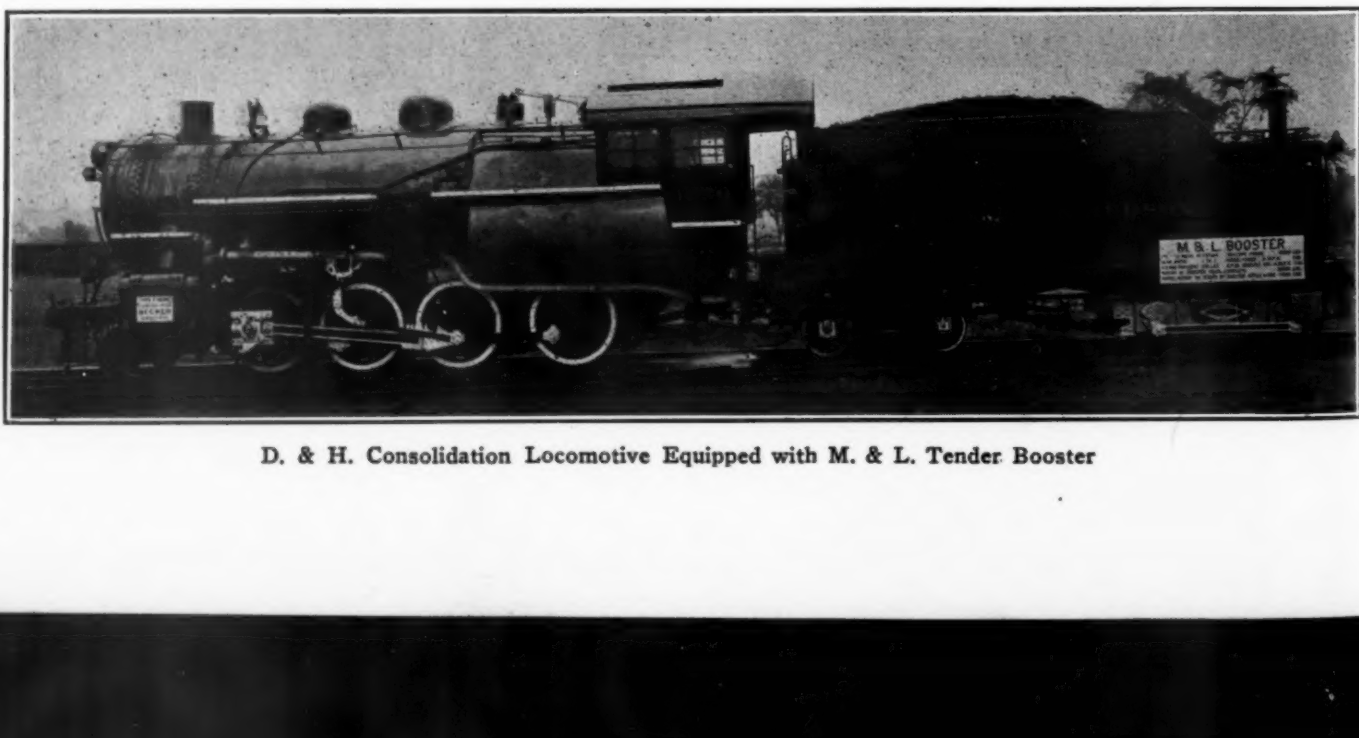
M. & L. Booster is Shown on D. & H. Locomotive

Among the track exhibits on Mississippi avenue will be found one of the D. & H. heavy Consolidation locomotives, the traction force of which is 55,000 lb. An M. & L. four-wheel booster has been applied to the rear truck of the tender. While several refinements in details have been made since the first on was placed in service on D. & H. locomotive No. 901 nearly two years ago, no essential changes have been found necessary as a result of continued use. In actual daily traffic an increase of 25 to 30 per cent. in tonnage is being hauled by locomotive No. 901 over that by other locomotives of the same class to which boosters have not been applied. A number of the M. & L. tender boosters are now in operation on the D. & H. and several have been supplied to the K. C. S.

The Booster under the tender of D. & H. locomotive No. 1050 has two 12-in. by 10-in. cylinders which drive one of the axles with a gear ratio of 2¼ to 1, the other axle being driven by connecting rods. With 250 lb. steam pressure and 36-in. wheels the tractive force of the booster is 18,000 lb. At a speed of 15 m. p. h. the booster engine makes 315 r. p. m. and develops 540 hp. The weight of the booster truck complete is 30,200 lb., the additional weight of a tender equipped with a booster being 14,000 lb. over one not so equipped. The piping connecting the main steam pipe on the left hand side of the locomotive with the booster cylinder is shown distinctly in the illustration. This pipe is equipped with Barco flexible joints.

Becker Wrist Pin

Another interesting and new attachment on this locomotive is the Becker wrist pin. This pin is slipped into place from the outside and is secured by a retaining gib and a taper key, the key being pulled down by a nut on the bottom. To loosen the wrist pin the key and gib are reversed, after which a blow with a sledge on the key is sufficient to start the wrist pin back and permit of its withdrawal outward. This wrist pin was designed by H. C. Becker, shop superintendent of the D. & H. at Colonie, N. Y.



D. & H. Consolidation Locomotive Equipped with M. & L. Tender Booster